PELVIC FLOOR STRENGTH AND SUPPORT IN HEALTHY NULLIPAROUS WOMEN:

FACTORS WITH STRENUOUS AND NONSTRENUOUS PHYSICAL ACTIVITY

by

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ABSTRACT

Pelvic floor disorders (PFD) affect 1 in 4 women with moderate to severe symptoms. Pelvic floor function has been widely studied in parous women, yet less is known about factors that may impact pelvic floor health in nulliparous women. Current and previous participation in strenuous physical activity has been cited as a potential contributing factor to pelvic organ prolapse (POP) and urinary incontinence (UI) in nulliparous women. Decreased pelvic floor muscle strength (PFMS) has been linked to PFD. We sought to (1) examine the difference in maximal vaginal descent (MVD) and PFMS between women who habitually perform strenuous exercise (SE) versus women who refrain from performing strenuous exercise (NSE), (2) to examine the difference in MVD and PFMS after an acute bout of strenuous (in SE) or nonstrenuous (in NSE) activity, and (3) to develop an exploratory prediction equation to identify predictors of PFMS in healthy nulliparous women.

Seventy healthy nulliparous women aged 18-35 yrs participated in the study (*n*=35 SE group, *n*=35 NSE group). Participants completed a test battery including anthropometric measures, behavioral measures, physical activity recall, appendicular muscle strength, and MVD, and PFMS by focused pelvic exam. Participants performed a bout of exercise and repeated PFMS and MVD measures.

MVD and PFMS were not different between SE and NSE women before exercise. After a bout of typical exercise, PFMS was maintained and pelvic floor support (MVD) decreased slightly in both groups. PFMS was unable to be predicted through anthropometric, behavioral, historical physical activity loads, and leg and arm muscular strength variables. No individual variable or group of variables for PFMS were identified as predictors of PFMS.

After a typical exercise bout, vaginal support decreased slightly in both SE and NSE women, suggesting muscle fatigue or connective tissue laxity after exercise. However, based on pre-exercise measures between groups, chronic strenuous exercise demonstrated neither beneficial nor deleterious effects on pelvic floor strength or support. It cannot be assumed that those with high arm or leg strength will have high PFMS. Targeted PFM strengthening, rather than general muscle fitness, may be needed to maximize PFMS.

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GLOSSARY OF COMMON TERMS

BMI:	Body mass index
BF%:	Body fat percentage
DAG:	Directed Acyclic Graph
IAP:	Intra-abdominal pressure
IRB:	Institutional review board
LBP:	Low back pain
NSE:	Nonstrenuous exercise group
PFD	Pelvic floor dysfunction
PFM	Pelvic floor muscles
PFMS:	Pelvic floor muscle strength
POP:	Pelvic organ prolapse
SUI:	Stress urinary incontinence
SE:	Strenuous exercise group
SD:	Standard deviation
UI:	Urinary incontinence
VIF:	Variation inflation factor

CHAPTER 1

INTRODUCTION

Introduction

Female sport participation and competition in the Olympic games has steadily increased since the inclusion of women in the 1900 Paris, France games. However, the greatest increases in women's sport participation in the United States began after the passing of Title IX legislation in 1972. With the provision of equal funding towards female participation in athletic endeavors through the passage of Title IX, many social stigmas and barriers to physical activity were reduced. In 1971-1972 reported female participation in high school athletics totaled 294,015 in all sports (National Federation of State High School Associations, 2014). Due to the opportunities that Title IX presented and with the diminishing social stigma surrounding women and physical activity, drastically higher participation rates were reported for females in all high school sports for the 2012-2013 school year, enumerating 3,222,723 females who participated (National Federation of State High School Associations, 2014). Many of these women go on to play at the collegiate level. The average number of NCAA varsity teams per school has risen from 2.5 in 1970 to 8.73 in 2012, and this year marks the highest female sport participation in history (Acosta & Carpenter, 2012).

Title IX legislation opened the door for women to compete in and enjoy the benefits of many sports, even those traditionally done only by men, such as marathon running, weight lifting, wrestling and ski jumping. Basketball, volleyball, softball, track and field, tennis, lacrosse, swimming and diving, competitive spirit squads, and gymnastics have been frequently listed in the top 10 most popular female sports in high school and college (Acosta & Carpenter, 2012; National Federation of State High School Associations, 2014). Recent high school trends have shown an increase in female participation rates in ice hockey, flag football, and wrestling. While there are many positive physical adaptations of sport participation, including increases in cardiovascular endurance, muscular strength, increased bone mineral density, flexibility, agility, balance, speed, coordination, and reaction time (Beachle & Earle, 2008), it is unknown if there are any deleterious effects on female function with increases in strenuous physical activity.

While there have been significant advances in understanding exercise physiology in women, it is unknown if there are any damaging ramifications of strenuous physical activity. While drastic increases in female sport participation have occurred since 1972, recently women have reported barriers to physical activity related to pelvic floor dysfunction, specifically urinary incontinence (Nygaard et al., 2005). Women report altering the type and quantity of physical activity performed, due to issues arising from pelvic floor disorders, which affect 1 in 4 women with moderate to severe symptoms (Nygaard et al., 2005; Nygaard, Shaw, & Egger, 2012; Nygaard, Barber, Burgio, et al. 2008).

Pelvic Floor Disorders

Pelvic floor disorders are a classification of disorders affecting the anatomy and functionality of the pelvic floor, which include urinary incontinence, fecal incontinence, and pelvic organ prolapse (POP). Longstanding beliefs regarding physical dangers associated with female participation in strenuous exercise can be traced back to Hippocrates (460-370 BC), who suggested that excessive exertion and fatigue were risk factors for pelvic dysfunction (Cardozo & Staskin, 2006). These beliefs have been largely put to rest, still some clinicians who specialize in the treatment of pelvic floor disorders recommend their patients refrain from engaging in such physical activity (Pelvic organ prolapse: A guide for women, 2011). Further, there have been limited data aiding the understanding of whether strenuous exercise contributes to the pathogenesis of POP.

Pelvic Organ Prolapse

POP is a disorder characterized by tissue laxity and eventual distension of pelvic organs into and out of the vaginal canal (Gill & Hurt, 1998). To date, no criterion measure exists for assessing the absence or presence of POP in a dichotomous classification, rather, the severity of prolapse is measured though a pelvic organ prolapse quantification system (POP-Q) (Bump, et al. 1996). The POP-Q is a reproducible measure of vaginal support, and provides measures of maximal vaginal descent (MVD) during a full-exertion Valsalva maneuver (Hall et al., 1996; Kobak, Rosenberger, & Walters, 1996). MVD from the anterior and posterior vaginal wall have a possible range of values from -3cm to +3cm, with negative results indicating values superior to the introitus, and positive results indicating values inferior of the introitus (Bump et al. 1996). Prevalence rates for POP differ due to variations in diagnostic criteria, examination techniques used, and differences in the researched populations (Culligan, & Goldberg, 2006). A Swedish study of 487 women found that the prevalence of POP differed by age, parity, and pelvic floor muscle strength. Twenty to twenty-nine year-old women had a 6.6% prevalence rate of any form of POP, while 50-59 year old women had a significantly higher 55.6% prevalence rate (Samuelsson, Victor, Tibblin, & Svardsudd, 1999). Additionally, parous women experienced a higher prevalence rate (44.0%) of any form of POP compared to nulliparous women (5.8%). The pathogenesis of POP is not fully understood in nulliparous or parous women, but the initiating factors may be different with the absence or presence of vaginal delivery, which is a known risk factor for POP.

Risk Factors for Pelvic Organ Prolapse

POP is thought to develop over time due to damage to the pelvic support system (Gill & Hurt, 1998). Risk factors for POP include connective tissue disorders, pelvic neuropathies, pelvic surgery, obesity, respiratory disorders, joint hypermobility, physical activity (Gill & Hurt, 1998), levator ani defects (Brækken, Majida, Ellstro¨m Engh, Holme, & Bø, 2009), and issues arising from vaginal delivery (i.e., levator ani tears, forceps delivery, anal sphincter tear) (Gill & Hurt, 1998).

Vaginal delivery is a large initiating factor of POP (Gill & Hurt, 1998), but this does not apply to nulliparous women regardless of physical activity level. Physical activity associated with increased intra-abdominal pressure may worsen the severity of POP (Ali-Ross, Smith, & Hosker, 2008), yet the extent of POP severity directly attributed to physical activity is unknown. Many studies have examined a similar pelvic floor measure of stress urinary incontinence (SUI). A 2009 case-control (age and parity matched) study concluded that the pathophysiology of SUI and POP might not be the same, even though the symptoms frequently overlap (Brækken, Majida, Ellstro¨m Engh, Holme, & Bø, 2009).

Strenuous Physical Activity and Pelvic Floor Function

Studies examining SUI have proposed that high-intensity impact exercise may change the muscular function of the pelvic floor, especially during landing (Bo & Borgen, 2001; Eliasson, Larsson, & Mattsson, 2002; Nygaard, Thompson, Svengalis, & Albright, 1994; Thyssen, Clevin, Olesen, & Lose, 2002). After a bout of physical activity, 25% of older women seeking care for POP experienced a worsening POP stage (Ali-Ross, Smith, & Hosker, 2008), yet this change in pelvic floor function after a bout of physical activity in younger nulliparous women is unknown. Females in high school and college athletics are participating in sports that repeatedly require strenuous, high-intensity physical exertion. Due to the high prevalence of pelvic floor disorders, (1 in 4 women present with moderate to severe symptoms) (Nygaard, Barber, Burgio, et al. 2008) and the specialization of sport from an early age, young, healthy women may be at increased risk for developing POP due to the quantity of strenuous training at an early age. Noncontact musculoskeletal and connective tissue injuries of the ACL are more prevalent in females compared to males in athletics, especially during high school (ratio of female to male rate of injury= 4.50) and college years (ratio of female to male rate of injury= 3.63), which might be indicative of higher risk for other connective tissue injury with strenuous physical activity (Renstrom et al., 2008). Many female exercisers of varying levels are exposed to physical impact and increased ground reaction force during training. Paratrooper training resulted in an increase in stage II POP prevalence and worsening pelvic floor support in nulliparous college-age paratrooper recruits (Larsen & Yavorek, 2007). These authors proposed that the excess force applied to the pelvic floor while absorbing force from paratrooper landings contributed to laxity and eventual POP in the healthy young women in their study (Larsen & Yavorek, 2007), yet it is unknown if this laxity persisted over time.

Women and Physical Activity

Recent reports indicate that 53.9% of females 18-44 yrs, and 49.4% of females 25-64 yrs met the CDC physical activity guidelines (CDC: BRFSS, 2013). While many women fail to meet the CDC guidelines, some women are participating in high-intensity interval training (HIIT), which was named in the top 10 fitness trends for 2014 in a recent survey conducted by the American College of Sports Medicine (Thompson, 2013). HIIT favors greater subcutaneous fat loss when compared to moderate-intensity exercise, due to the increase in postexercise lipid utilization (Tremblay, Simoneau, & Bouchard, 1994), offering faster body composition-related results compared to traditional steady-state exercise. HIIT has gained popularity in younger adults, including programs such as P90X®, Insanity®, Tabata-style training, kettle-bell-based exercise, CrossFit™, bootcamp-style exercise, and other, newly emerging exercise programs.

A record number of female high school athletes are participating in sports that demand high physical intensity and strenuous effort (National Federation of State High School Associations, 2014). The group environment, similar to competitive athletics or military-style training of strenuous exercise, has grained significant popularity in young adults, including females. In 2002 Greg Glassman founded CrossFit™ in an attempt to change the approach for those seeking to improve physical fitness. CrossFit™ has gained significant popularity since its conception. A CrossFit™ workout is characterized by high intensity, power-based exercises emphasizing Olympic lifts, gymnastics, and plyometric training. This type of habitual strenuous exercise is an ideal model for studying the effects of high intensity, strenuous training on pelvic floor function. Despite its popularity, there are limited published reports on men and women who regularly participate in CrossFit™. A Pubmed, Scopus, and SportDiscus search returned only 13 peer-reviewed articles using the search term "CrossFit." The little research that does not focus on motivation factors, personal enjoyment, or education that is available has not been well designed, with flaws that limit credibility and generalizability. A 10-week CrossFit™-based exercise program in females elicited an increase in aerobic fitness (VO_{2max} pre 35.98 ± 1.60, VO_{2max} post 40.22 ± 1.62 $ml \cdot kg^{-1} \cdot min^{-1}$, $P<0.05$) and a decrease in body composition (body fat % pre 26.6 ± 2.0, body fat % post 23.2 ± 2.0, $P<0.05$) (Smith, Sommer, Starkoff, & Devor, 2013), yet this research did not include a control group. While evidence points to improvements in physical fitness with CrossFit™ participation, which has direct ties to health outcomes, the effects of this type of physical exertion on pelvic floor function are largely unknown. Excessive intra-abdominal pressures experienced during CrossFit™ may be considered detrimental to pelvic floor health by some, while others may propose CrossFit™ training could be beneficial to the pelvic floor by strengthening muscles and connective tissues.

Pelvic Floor Muscle Function

Skeletal muscle strength increases with resistance training (Beachle & Earle, 2008). Kegel exercise, the purposeful contraction of the pelvic floor musculature, has been shown to be effective in reducing SUI symptoms (Bo, 2007). Significant improvements in POP severity have not been demonstrated with pelvic floor muscle training exercise, which makes drawing conclusions regarding training and strength increases in the pelvic floor difficult at best (Bø, Hilde, Stær-Jensen, et al., 2015). MRI and ultrasound data collected in elite nulliparous athletes indicated an increase in the area of the levator ani, thickening of the pubovisceral muscle diameter, and increased distensibility of these muscles during Valsalva, when compared to their nonathletic counterparts (Kruger, Deitz, & Murphy, 2007; Kruger, Murphy, & Heap, 2005). Kruger and colleagues suggested that the increase in intra-abdominal pressure with the cocontraction of the abdominal and pelvic floor muscles during repeated impact upon landing alters the pelvic floor structures and function. While these authors have shown that pelvic musculature is altered in nulliparous athletes, it is unknown if pelvic floor muscle strength increases directly due to increases in intra-abdominal pressure.

A pelvic floor muscle strength (PFMS) test is a clinical assessment, which seeks to identify pelvic floor muscle strength through measures of pressure during isometric contraction using tactile feedback or through the use of a perineometer. A vaginal perineometer is a more objective measure of PFMS compared to palpation-based tests (e.g., the Brinks strength test and the Oxford grading system) and is used to identify pressure produced during rest and contracted conditions. A Peritron vaginal perineometer (*Laborie*, Canada) can evaluate the maximal pressure produced, the average pressure produced, and the duration of a contraction. The existing measures of pelvic muscle strength, the Brinks strength test, a subjective measure used by a trained clinician to evaluate PFMS by palpation, and the much lesser used pelvic floor dynamometry, are not routine, nor are they desirable assessments for most women.

Measures of skeletal muscle strength assessed at different anatomical locations tend to be correlated with each other (Rantanen, Era, & Heikkinen, 1994). Handgrip strength has been used in many studies as a proxy for total body strength, since it tends to correlate with other measures of muscle strength and is more feasible to assess than other body segments (Ling, de Craen, Slagboom, Westendorp, & Maier, 2012). Following this pattern, it would seem plausible that measures of skeletal muscle strength of the arms and legs, that is, appendicular strength, may be related to PFMS. If this were the case, it would be advantageous to assess appendicular strength as a proxy measure for PFMS, thereby obviating the need for a pelvic exam. While research in parous women has found it difficult to determine relationships between various measures of pelvic floor muscle strength and function, little is known about whether traditional measures of skeletal muscle strength, total body muscularity, and other behaviors that could influence pelvic floor function are predictive of PFMS. Further, predicting PFMS may be less complicated in nulliparous women, in whom pelvic structures have not been altered due to childbirth.

Statement of the Problem

One in 4 women present with moderate to severe symptoms for POP (Nygaard, Barber, Burgio, et al. 2008), yet little is known about why and how POP develops. While many risk factors have been identified, vaginal delivery remains as the one consistent risk factor; yet not all women who have a vaginal delivery incur POP. Prevalence data indicate that young women have greater noncontact, musculoskeletal and connective tissue injury than boys. Does this infer that strenuous activity performed by young women raises the risk of developing POP, even prior to childbirth? Assessing the pelvic floor musculature and function by PFMS and MVD in women who have not experienced childbirth allows for the comparison of chronic participation in different types of physical activity. Specifically, does regular participation in strenuous activity versus nonstrenuous activity result in MVD and PFMS differences in nulliparous women, and are changes in these measures observed with acute exercise? High levels of PFMS may decrease the risk for POP by providing support of the pelvic viscera. Knowing factors that predict PFMS could set the stage for prevention strategies in women preparing for future pregnancy.

Research Aims and Hypotheses

Aim 1a: To examine the difference in MVD by POP-Q between women who habitually perform strenuous exercise (SE) versus women who refrain from performing strenuous exercise (NSE). Aim 1a hypothesis: Women who habitually perform strenuous activities (SE) will have a lower MVD indicating greater vaginal support, compared to women who habitually perform nonstrenuous (NSE) activities.

Aim 1b: To examine the difference in pelvic floor strength between women who habitually perform strenuous exercise (SE) versus women who refrain from performing strenuous exercise (NSE). Aim 1b hypothesis: Pelvic floor strength will be greater in women who habitually perform strenuous activities (SE), compared to women who habitually perform nonstrenuous activities (NSE).

Aim 2a: To examine the difference in MVD by POP-Q after an acute bout of strenuous or nonstrenuous activity among women who habitually perform strenuous exercise (SE) versus women who refrain from performing strenuous exercise (NSE). Aim 2a hypothesis: The change in MVD (post-pre) after an acute bout of exercise will be greater in women who habitually perform strenuous activities (SE), compared to women who habitually perform nonstrenuous (NSE) activities. It is expected that MVD will increase after an intense, high-impact exercise session in women who habitually perform strenuous activities (SE), while no discernable change will be present in women who habitually perform nonstrenuous (NSE) activities.

Aim 2b: To examine the difference in pelvic floor strength after an acute bout of strenuous or nonstrenuous activity among women who habitually perform strenuous exercise (SE) versus women who refrain from performing strenuous exercise (NSE). Aim 2b hypothesis: The change in pelvic floor strength (post-pre) after an acute bout of exercise will be greater in women who habitually perform strenuous activities (SE), compared to women who habitually perform nonstrenuous (NSE) activities. It is expected that pelvic floor strength will decrease after an intense, high-impact exercise session in women who habitually perform strenuous activities (SE), while no discernable change will be present in women who habitually perform nonstrenuous (NSE) activities.

Aim 3: To develop two pilot prediction equations through multiple regression for PFMS by Peritron perineometer for women who participate in strenuous exercise (SE) and for women who do not do strenuous exercise (NSE), to include waist circumference, body composition, straining to defecate, caffeine consumption, bone loading in junior high and high school years, and isometric upper and lower body strength in the equations. Aim 3 hypothesis: It is expected that elbow and knee isometric strength (flexion and extension MVC in N/m) will be significant predictors of pelvic floor strength as measured by the maximal PFMS.

Significance of Study

The results of this proposed study will provide insight into the function of the pelvic floor in women who habitually perform strenuous exercise and in nulliparous women who refrain from doing strenuous exercise. While strenuous physical activity has many potential physiologic benefits, it is unknown if this type of physical activity has deleterious effects on the pelvic floor, especially later in life. The data provided from this study will help to identify potential factors in the pathogenesis of POP. Quantifiable data on pelvic floor function at rest and after an acute bout of exercise will provide insight into the chronic and acute impact of strenuous physical activity on vaginal support in women who have not experienced pregnancy.

Pelvic floor strength, rather than MVD and pelvic symptoms, may provide significant insights into the function of the pelvic floor. The development of two pilot prediction equations may provide clinicians with a more desirable option by allowing them to perform a simple test battery instead of undergoing a pelvic exam. If the evaluation of the regression equation is shown to be effective through cross-validation, the prediction of pelvic floor strength may identify women who are at increased risk of developing a pelvic floor disorder so that preventive measures or therapeutic interventions can be considered.

Methods

Participant Recruitment and Screening

Participants were recruited through advertisements throughout the greater Salt Lake City, UT, specifically at the University of Utah, throughout the local CrossFit™ community, and by word of mouth. All study procedures were reviewed and approved by the University of Utah IRB prior to data collection and eligible participants provided written consent. Potential participants were screened in person or by phone to determine study eligibility. To be eligible for participation, women were ≥ 18 and ≤ 35 years, and answered "no" to all questions on the Physical Activity Readiness Questionnaire (PAR-Q; See Appendix A), women were nulliparous, nonsmoking, free of musculoskeletal injuries for the past 6 months, had already experienced at least one pelvic exam, were relatively weight stable (no more than ~10% body mass fluctuation) in the past six months, and were willing to complete two POP-Q examinations and other study measures.

Specific inclusion criteria for those in the SE group included at least 6 months of consistent participation in CrossFit™, completing at least three workouts per week, with no history or current use of performance-enhancing substance by self-report. All SE participants demonstrated the ability to properly execute the prescribed lifts in the exercise protocol. Potential participants in the SE group were excluded if they reported history of hysterectomy or pelvic surgery to correct prolapse or incontinence or chronic cough on medical history.

Women in the NSE group had not been participating in any consistent form of heavy resistance, conditioning or routine impact activity over the past 6 months. Women in the NSE group were excluded if they reported history of hysterectomy or pelvic surgery to correct prolapse or incontinence, chronic cough, or if physical activity assessment indicated that they regularly engaged in heavy lifting or impact exercise.

Exercise Protocol

The SE and the NSE group exercise protocols were designed to reflect typical physical effort for women in each group. Women were asked to consume their last meal 3 hours prior to their scheduled exercise session and withhold exercise 24 hours prior to their scheduled exercise session. Participants were given 33.8 oz of water during the exercise session to be consumed as desired. Water consumption was recorded for descriptive purposes. To ensure that all participants were properly warmed up prior to exercise, and to stay consistent with a typical CrossFit™ workout, the SE group completed a 5-minute specific warm-up prior to the strenuous workout which, also mirrored recommendations by the NSCA (Beachle & Earle, 2008). The SE group warm up consisted of routinely used exercises during a CrossFit™ workout, including "good mornings" with an un weighted PVC pipe, overhead squat with a PVC pipe, inch-worms, and lunges repeated for a duration of 5-minutes. The warm-up for the NSE group consisted of low-intensity dynamic activities also consistent with NSCA recommendations (Beachle & Earle, 2008). The warm-up included one minute of walking at a self-selected pace, shoulder circles, body weight squats, standing butt-kickers, marching in place, and upper body rainbows to fully mobilize the shoulder joint, repeated for a duration of 5 minutes.

Strenuous Exercise Group

As outlined in Table 1.1, following the 5-minute warm-up, the SE group performed a 20-minute exercise bout that asked participants to complete the exercise selections with as many repetitions as possible in 20 minutes. CrossFit™ terminology calls this an AMRAP, as many rounds/repetitions as possible. Exercises that were selected are routinely performed in CrossFit™ and were not novel to the SE participants: 15 push-ups, 5 deadlifts at 80% of 3RM, 5 push-presses at 80% of 3RM, 15 burpees, and 20 sit-ups. Test administrators recorded heart rate (HR) in beats per minute (bpm), at rest and immediately upon completion of the 20-minute AMRAP. Rating of Perceived Exertion (RPE, Borg 6-20) (Borg, 1982) was recorded for the entire session as soon as postexercise HR was obtained. Session RPE has been shown to be a reliable measure of exercise intensity during resistance training (ICC= 0.88) (Day, McGuigan, Brice, & Foster, 2004). Test administrators counted and recorded the repetitions performed and the rounds completed.

Nonstrenuous Exercise Group

As outlined in Table 1.1, following the warm-up, the NS group was asked to complete a 20-minute walk at a self-selected pace. Participants were given the instructions to perform the walk at their chosen "exercise pace." Test administrators recorded HR at rest and immediately at the end of the 20-minute walk. RPE was recorded for the entire session as soon as postexercise HR was obtained. Distance was recorded by distance wheel for 20 minutes of walking and used to calculate average walking speed in kilometers per hour (km/hr).

Table 1.1: Protocol Overview for Sessions I and II

Session I	**Item Specific Details**
1. Screening/ Informed consent	Inclusion/Exclusion Criteria
2. PA and pelvic floor questionnaires	EPIQ, BLHQ and Medical History
3. Anthropometric data	Height, Mass, Waist:Hip, Bod Pod
4. Isometric strength MVC (dominant limb)	Elbow & Knee 90° Flexion & Extension
5. 3-RM prediction test (*SE group*)	Deadlift, Push-Press
Session II	**Item Specific Details**
1. Focused pelvic exam (pre-exercise)	POP-Q and PFMS
2. Exercise session by group	S group 20 minute AMRAP NS group 20 minute walk (self-selected exercise pace)
3. Focused pelvic exam (postexercise)	POP-Q and PFMS

POP-Q: Pelvic Organ Prolapse Quantification test
PFMS: Pelvic floor muscle strength
EPIQ: Epidemiology of Prolapse and Incontinence Questionnaire
BLHQ: Bone loading history questionnaire
MVC: Maximal voluntary contraction
3-RM: Three repetition maximum AMRAP: As many repetitions as possible

Order of Testing Protocol

Participants were asked to arrive to each testing session rested, reporting no exercise, normal dietary patterns, no central nervous system stimulants, and well hydrated, 24 hours prior to testing. A 2-session format was used. Session I: participants were presented with the informed consent documents, followed by administration of questionnaires (EPIQ, BLHQ, and a health history questionnaire). Height, weight, and body composition were obtained, followed by isometric strength testing on the elbow and knee of the dominant limbs using 90° flexion. The SE group performed 3RM testing to determine exercise session testing load (80% of the 3RM) for the deadlift and the push-press. Session II: Participants experienced a focused pelvic exam, followed by the appropriate exercise session for either the SE or NSE group. Upon completion of the exercise session the participants had a second focused pelvic exam, completing the testing protocol.

Anthropometric Measures

Height (cm), body mass (kg), and waist-to-hip ratio were measured using standardized procedures as recommended by the American College of Sports Medicine (ACSM) (2013). Participants were asked to remove shoes in order to obtain a height measurement. Height was measured using a stadiometer to the nearest 1.0 cm. Body mass was measured to the nearest 1.0 kg on an electronic Tanita scale, also without shoes. Waist and hip circumference measurements were taken using a standard tension-regulated tape measure. Body composition was analyzed using a Bod Pod (Cosmed Inc., Concord, CA), which has been shown to be a valid and reliable measure of body composition when compared to hydrostatic weighing in healthy adults (McCrory, Gomez, Bernauer, & Mole, 1995). Anthropometric measures were reported for descriptive purposes and as independent variables in for aim 3.

Self-Report Questionnaires

The Epidemiology of Prolapse and Incontinence Questionnaire (EPIQ) was administered to identify symptoms of pelvic floor disorders. The EPIQ identifies the subscales of urinary incontinence, fecal incontinence, pelvic organ prolapse, and overactive bladder, and has been validated in a similar population for women who were not seeking care for pelvic floor disorders (Lukacz, Lawrence, Buckwalter, et al. 2005).

The Bone Loading History Questionnaire (BLHQ) was administered to assess loads applied to the hip and spine (Dolan, Williams, Ainsworth, & Shaw, 2006), which demonstrated reliability in healthy premenopausal women (self-reported spine loading, r=0.89, self-reported hip loading r=0.92). This questionnaire was used to calculate bone loading exposure in specific age epochs as well as recent bone loading exposure at the hip and spine. The BLHQ is a valid measure of bone loading exposure that directly relates to bone mineral density, which is an adaptation of the applied physical exposure to the load. These values were used for descriptive measures. A health history questionnaire was administered to qualitatively assess family history of pelvic floor disorders, connective tissue disorders, current or previous back pain, diet, and other factors that could provide insight into pelvic floor function.

Isometric Strength Testing

To mirror the type of contraction performed during pelvic floor muscle contraction, isometric strength was assessed for elbow flexion and extension, knee flexion and extension on a Biodex isokinetic strength measurement device (Biodex Medical Systems, Inc., Shirley, NY). Maximal voluntary contraction (MVC) was assessed at the elbow and knee at 0°/sec at 90° of flexion, for both flexion and extension MVC at each joint. This isometric measure of torque provides units in N/m due to the moment arm present during contraction. The dominant limb performed 3 trials using an alternating agonist (flexion)/antagonist (extension) contraction for a total of 6 contractions for each limb. Each MVC lasted 10 seconds per trial followed by a 45-second rest. The sum of upper body flexion and extension (N/m) and, similarly, the sum of lower body flexion and extension (N/m) were used for descriptive purposes in aim 1 and 2, and were also used as independent variables in aim 3.

Focused Pelvic Exam

All participants completed two focused pelvic exams, one prior to exercise and one within 15 minutes upon the completion of an acute bout of exercise. In a private enclosed exam room, MVD was assessed by a certified research nurse using the POP-Q (Bump, Mattiason, & Bo, 1996), which is a reproducible and reliable measurement of MVD (Kobak, Rosenberger, & Walters, 1996). Women performed a Valsalva maneuver during the exam in a supine position to measure descent of the vagina in centimeters (cm). Participants were asked to void their bladder prior to beginning each exam before and after exercise.

Vaginal resting pressure and PFMS was assessed using Peritron 9300 V Vaginal Perineometer (*Laborie*, Canada), which is a clinical hand-held biofeedback device. VRP has been identified as an indicator of muscular closing of the lavator hiatus, and low VRP was found to produce the highest odds ratio for POP when combined with low PFMS (Brækken, Majida, Ellstro¨m Engh, Holme, Bø, 2009). The perineometer was used to assess VRP by calibrating the probe to zero before insertion, and asking each participant to completely relax after the pressure sensor probe was inserted. Without removing the probe, vaginal resting pressure and pelvic floor muscle strength were assessed after the probe was recalibrated to zero. Participants were asked to "squeeze and lift" strongly, for each of the three trials. On the fourth trial, the participant was asked to squeeze and "hold" with verbal prompts for 10 seconds while pelvic floor muscle endurance was evaluated. Maximal pressure for the three MVC trials, as well as the average contraction pressure, was used in analysis to evaluate pelvic strength.

The research nurse was masked to activity group and was not aware of the study aims. The focused pelvic exam was conducted in a different location from the exercise protocol. In addition, efforts were taken to wipe body sweat from participants and to reduce excess body heat in order to make groups appear as similar as possible. MVD and the pelvic strength values (pre- and postexercise) were used as descriptive measure of the SE and NSE group, and also as the dependent variables for aims 1 and 2.

3-Repetition Maximum Testing (Strenuous Exercise Group)

A repetition maximum (RM) is the highest weight lifted for a specified number of repetitions (Baechle & Earle, 2008). A 3-RM test was assessed according to the protocol outlined in the National Strength and Conditioning Association (NSCA) testing guidelines (Baechle & Earle, 2008) for the deadlift and the push-press. Participants were instructed to perform a 5-minute predetermined general warm-up followed by the specific warm up for the lift performed (e.g., the deadlift or the push-press). Participants were instructed to warm up with a weight that was light resistance, easily allowing 5-10 repetitions. After a 1-minute rest period a second warm up weight load was estimated by adding 10-20 lbs or 5-10% increase for the push-press, and 30-40 lbs or 10-20% for the deadlift, to the initial light load. After a 2-4-minute rest period, load was increased using the weight increment increases provided above, which are recommended by the NSCA, until the maximal load is lifted for 3 repetitions. The 3-RM data were used to calculate the load used in the exercise session (80% of the 3-RM) for the SE group.

Data Analysis

All statistical analyses were made using Stata version 13.1 (StataCorp, 2013. *Stata Statistical Software,* College Station, TX). To analyze the data for aim 1 means and standard deviations were used to provide descriptive statistics of the sample population. Descriptive pelvic floor measures for MVD pre- and postexercise were reported using the median with interquartile range (Q1 and Q3). Due to the nature of the groups including only healthy, young women, the MVD data were not normally distributed, which violates one assumption required for performing parametric statistics. Therefore nonparametric statistics were used to analyze the MVD from the POP-Q assessment between groups (pre-exercise SE and NSE) and within group (pre-postexercise values). Visual confirmation was used to identify normally distributed PFMS data using a histogram and a box plot, and therefore parametric statistics were used. A Wilcoxon Rank Sum test (a nonparametric alternative to the 2-sample *T*-test) was used to test the differences in MVD between SE and NSE groups. Independent samples 2-tailed *T*-tests were used to compare group means for PFMS and VRP between groups. Paired two-tailed *T*-tests were used to compare group means pre-to-postexercise for PFMS and VRP within each group (SE pre- vs. postexercise and NSE pre- vs. postexercise). An alpha level of 0.05 was established a priori.

To address aim 3, a visual assessment using histograms and box plots was used to identify the normality of the data. Means and standard deviations were used to provide descriptive statistics of the sample population. Independent *T*-tests identified potential differences between groups for independent and dependent variables. A correlation matrix and variation inflation factor (VIF) served to identify any variables that may have violated a multicollinearity assumption prior to conducting regression analyses.

To determine the best predictors of PFMS, a multiple linear regression was performed. To predict the outcome (dependent) measure PFMS, for the SE and NSE groups, the independent variables (1) waist circumference in cm, (2) body composition in kilograms (kg) of lean mass, (3) straining to defecate as dichotomous "yes" or "no", (4) caffeine consumption on a categorical scale of 0 to 4, (5) bone loading exposure for the spine and hip in Jr High in BLU (6) bone loading exposure for the spine and hip in High School in BLU, (7) the sum of isometric upper body strength in N/m, and (8) the sum of isometric lower body strength in N/m were entered simultaneously into the regression model. These were exploratory prediction equations and therefore no theoretical indications pointed toward hierarchical or empirically driven approaches.

Power Analysis

A priori calculations determined that a sample size of 35 per group would provide approximately 80% power at the 5% significance level to detect a medium effect size (Cohen's W=0.375) for the difference in MVD between the SE and NSE groups, assuming women will fall into one of 3 categories of MVD (-3,-2,-1 cm), using a 2x3 chi-squared test. This sample size also would provide approximately 87% power to detect a pre-post difference in PFMS within a single exercise group of 4.5 cm H_20, assuming normality and a standard deviation of differences of 8.1, again at the 5% significance level, using a paired T-test for aims 1 and 2. It is reasonably assumed that aim 3 will be underpowered, but this is an acceptable risk due to the exploratory nature of the prediction of PFMS.

CHAPTER 2

THE IMPACT OF ACUTE AND CHRONIC STRENUOUS EXERCISE ON PELVIC FLOOR MUSCLE STRENGTH AND SUPPORT IN NULLIPAROUS HEALTHY WOMEN

Abstract

Background: Strenuous physical activity, which is known to increase intra-abdominal pressure and theoretically places stress on the pelvic floor, may affect pelvic support in nulliparous women. Objectives: The aims of this study were (1) To examine the differences in maximal vaginal descent (MVD), vaginal resting pressure (VRP), and pelvic floor muscle strength (PFMS) between women who habitually perform strenuous exercise (SE group) versus women who refrain from performing strenuous exercise (NSE group), and 2) to compare MVD, VRP, and PFMS before and immediately following physical activity in the SE and NSE groups separately. Participants were healthy nulliparous women ages 18-35 years who were habitual strenuous or nonstrenuous exercisers. Women in the SE group participated in CrossFit™ at least 3 days per week for at least 6 months. We assessed anthropometric and body composition values using standardized procedures. Participants completed the Pelvic Organ Prolapse Quantification (POP-Q) examination and pelvic muscle strength assessment before and again within 15 minutes of completing exercise (CrossFit™ for the SE and self-paced walking for the NSE groups). A research nurse masked to study group assignment recorded MVD, defined as the greatest value of anterior, posterior or apical support measured by the POP-Q, and VRP and PFMS using a perineometer. Maximal PFMS was recorded as the highest pressure measured in 3 vaginal contraction trials. Data were analyzed using parametric and nonparametric tests as appropriate. $P < 0.05$ was considered significant.

Seventy nulliparous women participated in the study, 35 in each group. The mean age was 24.77 ± 4.3years. Compared to the NSE group, SE participants were heavier

(64.70 ± 7.78 kg vs 60.6 ± 8.99 kg, P=0.027), had lower percent body fat (23.36 ± 5.88 % vs 27.55 ± 7.07 %, P=0.003) and higher handgrip strength (45.71 ± 13.13 lbs vs 35.29 ± 11.87 lbs, P=0.001). Before exercise, the SE group had higher VRP than the NSE group (P=0.03), but there were no significant differences in MVD (P=0.49) or maximal PFMS (P= 0.83) between the SE and NSE groups. Immediately following exercise, we observed significant increases in MVD in both the SE (P= 0.008) and NSE (P=0.025) groups, indicating marginal decreases in support. VRP significantly decreased in the SE group, but not in the NSE group. Maximal PFMS did not change significantly in either group after exercise. Conclusions: After an exercise bout typical for each group, vaginal support decreased slightly in both groups and VRP decreased only in SE women, suggesting potentially greater muscle fatigue after CrossFit™. However, based on pre-exercise measures, chronic strenuous exercise demonstrated neither beneficial nor deleterious effects on pelvic floor strength or support. While SE women had greater grip strength than NSE women, PFMS was not significantly greater, suggesting that targeted PFM strengthening, rather than general muscle fitness, is needed to maximize PFMS.

Introduction

Participation in structured physical activity leads to many health benefits, including decreased risk of all-cause mortality, decreased disease-specific risk, and strengthening of the muscular system (Baechle & Earle, 2008). Participation in physical activity is generally considered safe, yet strenuous and/or repetitive physical activity of long duration can increase the risk for muscular, tendon, and ligamentous damage (Renstrom & Johnson, 1985). Whether strenuous physical activity increases risk for pelvic floor disorders is not known.

Pelvic floor disorders include dysfunction in the pelvic support structures with presentations including urinary incontinence, anal incontinence, and pelvic organ prolapse (POP). POP is characterized by decreased pelvic support, demonstrated by tissue laxity and descent of the pelvic organs into or out of the vagina. One in 4 women in the United States experience moderate to severe symptoms of at least one pelvic floor disorder (Nygaard, Barber, Burgio, et al., 2008), including POP, which can negatively impact quality of life and may be a barrier to future physical activity. Women have reported worsening POP symptoms after prolonged periods of standing, lifting, and in the evening (Sung, Clark, Sokol, Rardin, & Myers, 2007), indicating that fatigue may contribute to POP. After a bout of physical activity, women with POP demonstrated decreased pelvic support upon POP-Q examination, but this decrease in support was not associated with worsening of self-report POP symptoms (Ali-Ross, Smith, & Hosker, 2008).

Nulliparous paratrooper military recruits who routinely experienced forceful landings along with regular basic training were more likely to have stage II POP when compared to military recruits who performed basic training only (Larsen & Yavorek, 2007), indicating that the added strain of impact during landing resulted in reduced pelvic support. Kruger and colleagues suggested that increases in intra-abdominal pressure with cocontraction of the abdominal and pelvic floor muscles during repeated impact upon landing alters the pelvic floor structures and function (Kruger, Deitz, & Murphy, 2007; Kruger, Murphy, & Heap, 2005). While it has been shown that pelvic musculature is altered in nulliparous athletes, it is unknown if pelvic floor muscle strength increases with increases in intra-abdominal pressure. With the increased popularity of strenuous exercise programs, concern has been raised over the safety of strenuous physical activity on pelvic floor function. A CrossFit™ workout is characterized by high-intensity activities that are highly variable, including power-based exercises emphasizing Olympic lifts, gymnastics, and plyometric training. This type of habitual, strenuous exercise is an ideal model for studying the impact of high-intensity, strenuous training on pelvic floor function. Aim 1a: To examine the difference in MVD by POP-Q between women who habitually perform strenuous exercise (SE) through CrossFit™ versus women who refrain from performing strenuous exercise (NSE). Hypothesis: Women who habitually perform strenuous activities (SE) will have a lower MVD, indicating greater vaginal support, compared to women who habitually perform nonstrenuous (NSE) activities. Aim 1b: To examine the difference in pelvic floor strength between SE and NSE groups. Hypothesis: Pelvic floor muscle strength will be greater in SE, compared to pelvic floor muscle strength in NSE. Aim 2a: To examine the acute difference in MVD by POP-Q after a habitual bout of strenuous or nonstrenuous activity among SE versus NSE participants. Hypothesis: The change in MVD (post-pre) will be greater in SE, compared to NSE. It is expected that MVD will increase after an intense, high-impact exercise session in SE, while no discernable change will be present in NSE. Aim 2b: To examine the acute difference in pelvic floor muscle strength after a typical bout of strenuous or nonstrenuous activity among women who habitually perform strenuous exercise (SE) versus women who refrain from performing strenuous exercise (NSE). Hypothesis: The change in pelvic floor muscle strength (post-pre) will be greater in SE, compared to NSE. It is expected that pelvic floor muscle strength will decrease after an intense, high-impact exercise session in SE, while no discernable change will be present NSE.

Methods

Participant Recruitment and Screening

Participants were recruited through advertisements throughout the greater Salt Lake City, UT area, specifically at the University of Utah, throughout the local CrossFit™ community, and by word of mouth. All recruitment and study procedures were reviewed and approved by the University of Utah Institutional Review Board prior to data collection and eligible participants provided written consent. To be eligible for participation, women were ≥ 18 and ≤ 35 years, and answered "no" to all questions on the Physical Activity Readiness Questionnaire (PAR-Q; See Appendix), women were nulliparous, nonsmoking, free of musculoskeletal injuries for the past 6 months, had already experienced at least one pelvic exam, were relatively weight stable (no more than ~10% body mass fluctuation) in the past six months, and were willing to complete two POP-Q examinations and other study measures.

Women in the NSE group had not been participating in any consistent form of heavy resistance, conditioning, or routine impact activity over the past 6 months. Specific inclusion criteria for those in the SE group included at least 6 months of consistent participation in CrossFit™, completing at least 3 workouts per week, with no history or current use of performance-enhancing substance by self-report. All SE participants demonstrated the ability to properly execute the prescribed lifts in the exercise protocol. Women were excluded if they reported history of hysterectomy or pelvic surgery to correct prolapse or incontinence, or chronic cough.

Order of Testing Protocol

Participants were asked to arrive to each testing session rested, reporting no exercise, normal dietary patterns, no central nervous system stimulants, and well hydrated, 24 hours prior to testing. A 2-session format was used.

Session I

Participants completed the informed consent process, followed by the administration of self-report questionnaires, anthropometric measures, and strength testing.

Self-Report Questionnaires

The Epidemiology of Prolapse and Incontinence Questionnaire (EPIQ) was administered to identify symptoms of pelvic floor disorders (Lukacz, Lawrence, Buckwalter, et al. 2005). The EPIQ identifies the subscales of urinary incontinence, fecal incontinence, pelvic organ prolapse, and overactive bladder and has been validated in a similar population for women who were not seeking care for pelvic floor disorders (Lukacz et al. 2005). The Bone Loading History Questionnaire (BLHQ) was administered to assess loads applied to the hip and spine (Dolan, Williams, Ainsworth, & Shaw, 2006), which demonstrated reliability in healthy premenopausal women (self-reported spine loading, r=0.89, self-reported hip loading r=0.92) and validity in comparison to spine and hip areal bone mineral density. This questionnaire was used to calculate bone-loading exposure in specific age epochs as well as recent bone loading exposure at the hip and spine. Total bone loading is a cumulative measure summing all of the age-available epochs, while total exposure is corrected for number of years to reflect the average exposure from elementary school until the participant's current age. While we were not assessing bone health, this questionnaire specifically addresses the type of activity thought to place strain on the pelvic floor. A health history questionnaire (See Appendix B) was administered to qualitatively assess family history of pelvic floor disorders, connective tissue disorders, current or previous back pain, diet, and other factors that could provide insight into pelvic floor function.

Anthropometric Measures

Height, body mass, and waist-to-hip ratio were measured using standardized procedures as recommended by the American College of Sports Medicine (ACSM) (2013). Participants were asked to remove shoes in order to obtain a height measurement. Height was measured using a stadiometer to the nearest 1.0 cm. Body mass was measured to the nearest 1.0 kg on an electronic Tanita scale, also without shoes. Waist and hip circumference measurements were measured using a tension-regulated tape measure. Body composition was analyzed using a Bod Pod (Cosmed Inc., Concord, CA), which has been shown to be a valid and reliable measure of body composition when compared to hydrostatic weighing in healthy adults (McCrory, Gomez, Bernauer, & Mole, 1995).

Isometric Strength Testing

To mirror the type of contraction performed during vaginal contraction, isometric strength was assessed for elbow flexion and extension, and knee flexion and extension on a Biodex isokinetic strength measurement device (Biodex Medical Systems, Inc., Shirley, NY). Maximal voluntary contraction (MVC) was assessed at the elbow and knee at 0deg/sec at 90 degrees of flexion, for both flexion and extension at each joint. The resulting units of N/m reflect the torque produced by the specified limb, while there is no movement in the joint, there is a moment arm present during the contraction. The dominant limb performed three trials using an alternating agonist (flexion)/antagonist (extension) contraction for a total of six contractions for each limb. Each MVC lasted 10 seconds per trial, followed by 45 seconds of rest. The SE group only performed 3-repetition maximum (RM) testing to determine exercise session testing load, which was set at 80% of the 3RM for the deadlift and the push-press exercises.

3-Repetition Maximum Testing: Strenuous Exercise Group Only

A repetition maximum (RM) is the highest weight lifted for a specified number of repetitions (Baechle & Earle, 2008). A 3RM test was assessed according to the protocol outlined by the National Strength and Conditioning Association (NSCA) (Baechle & Earle, 2008) for the deadlift and the push-press to calculate the 80% of the 3-RM, the workload to be used during the 20-minute strenuous exercise bout.

Session II

Participants completed a focused pelvic exam twice. The first was before the designated exercise session for the SE and NSE groups, and the second was done within 15 minutes of exercise completion. Women were asked to consume their last meal 3 hours prior to Session II. Water consumption during exercise was recorded for descriptive purposes.

Focused Pelvic Exam

Participants voided their bladders prior to each exam. In a private enclosed exam room, MVD was assessed by a certified research nurse using the POP-Q (Bump, Mattiason, & Bo, 1996), which is a reproducible and reliable measurement of MVD (Kobak, Rosenberger, & Walters, 1996). Pelvic floor muscle strength (PFMS) was assessed using Peritron 9300 V Vaginal Perineometer (*Laborie*, Canada). The perineometer was used to assess vaginal resting pressure (VRP), maximal pelvic floor strength (MaxPFMS), average pelvic floor muscle strength (AvgPFMS) for three MVC trials. VRP has been identified as an indicator of muscular closing of the lavator hiatus, and low VRP was found to produce the highest odds ratio for POP when combined with low PFMS (Brækken, et al., 2009). Women performed a Valsalva maneuver during the exam in a supine position to measure descent of the vagina in centimeters (cm). The perineometer was used to assess VRP by calibrating the probe to zero before insertion, and asking each participant to completely relax after the pressure sensor probe was inserted. Without removing the probe, pelvic floor muscle strength was assessed after the probe was recalibrated to zero. Participants were asked to "squeeze and lift" strongly, for each of the three trials. On the fourth trial, the participant was asked to squeeze and "hold" with verbal prompts for 10 seconds while pelvic floor muscle endurance was evaluated. Maximal pressure for the three MVC trials, as well as the average contraction pressure, was used in analysis to evaluate pelvic strength.

Exercise Protocol

The SE and the NSE group exercise protocols were designed to reflect typical physical effort for women in each group. To ensure that all participants were properly warmed up prior to exercise, a 5-miute warm-up was implemented prior to initiating the exercise protocol. The warm-up was activity-specific for each group, and engaged the muscular and circulatory systems at relatively low intensity to be consistent with the recommendations provided by the NSCA (Beachle & Earle, 2008).

Strenuous Exercise Group

As outlined in Table 2.1, following the 5-minute warm-up, the SE group performed a 20-minute exercise bout that instructed participants to complete the exercise selections with as many repetitions as possible in 20 minutes. CrossFit™ terminology calls this an AMRAP (as many rounds/repetitions as possible). Exercises that were selected are routinely performed in CrossFit™ and were not novel to the SE participants: 15 push-ups, 5 deadlifts at 80% of 3RM, 5 push-presses at 80% of 3RM, 15 burpees, and 20 sit-ups. Immediately upon completion of the 20-minute AMRAP, administrators recorded the repetitions performed, rounds completed, heart rate (HR, bpm), and session Rating of Perceived Exertion (RPE) based on the 15-point scale. Session RPE has been shown to be a reliable measure of exercise intensity during resistance training (ICC= 0.88) (Day, McGuigan, Brice, & Foster, 2004).

Table 2.1: Testing Order and Events

Session I	Item Specific Details
1. Screening/ Informed consent	Inclusion/Exclusion Criteria
2. PA and pelvic floor questionnaires	EPIQ, BLHQ and Medical History
3. Anthropometric data	Height, Mass, Waist:Hip, Bod Pod
4. Handgrip strength (dominant hand)	Elbow at 90° flexion
Session II	**Item Specific Details**
1. Focused pelvic exam (pre-exercise)	POP-Q and PFMS
2. Exercise session by group	SE group 20 minute AMRAP NSE group 20 minute walk (self-selected exercise pace)
3. Focused pelvic exam (postexercise)	POP-Q and PFMS

POP-Q: Pelvic Organ Prolapse Quantification test
PFMS: Pelvic floor muscle strength
EPIQ: Epidemiology of Prolapse and Incontinence Questionnaire
BLHQ: Bone loading history questionnaire
AMRAP: As many rounds or repetitions as possible

Nonstrenuous Exercise Group

As outlined in Table 2.1, following the warm up, the NS group was asked to complete a 20-minute walk at a self-selected pace. Participants were given instructions to walk at their "exercise pace." Immediately upon completion of the 20-minute walk, administrators recorded walking distance (total feet walked), HR, and session RPE. One research nurse conducted all pelvic exams for the study, she was masked to activity group and was not aware of the study aims. Efforts were taken to wipe body sweat from SE participants and to make both groups appear as similar as possible. SE participants were asked to refrain from wearing clothing with CrossFit™ emblems, logos, or specific terminology. Both groups were asked to remove shoes prior to entering the examination room, as CrossFit™ footwear could have identified the specific group.

Data Analysis

Data were analyzed using Stata 13.1 (StataCorp. 2013. *Stata Statistical Software,* College Station, TX). Means and standard deviations were used to provide descriptive statistics of the sample population (Table 2.2). Two-tailed *T*-tests were used to identify differences in groups' means for descriptive data. Descriptive pelvic floor measures for MVD pre- and postexercise were reported using the median with quartiles Q1 and Q3 (Table 2.3). Only healthy, young women were included in this study, so the ordinal MVD data did not span their full range (-3 to +3) in the population and were not normally distributed. Therefore, the Wilcoxon rank sum test was used to analyze MVD between SE and NSE groups pre-exercise, and the Wilcoxon signed rank test was used to analyze MVD values pre-postexercise within each group.

After discovery of an error in how VRP was obtained at the beginning of the study, we discarded the first 7 values for VRP in our analyses. Shapiro-Wilk tests, used to assess approximate sample normality, were performed for VRP after the 7 data points were removed and for all participants for PFMS. These tests indicated a nonnormal distribution for all outcome measures, and therefore nonparametric testing was performed for these variables. The Wilcoxon rank-sum was used to compare group medians for PFMS and VRP. The Wilcoxon signed rank was used to compare group medians pre- to postexercise for PFMS and VRP within each group (SE pre- vs. postexercise and NSE pre- vs. postexercise). An alpha level of 0.05 was established a priori.

Table 2.2: Subject Characteristics

	Strenuous (SE) Group, *n*= 35	Nonstrenuous (NSE) Group, *n*= 35	Total	*P* value
Age (yr)	26.8 ± 3.79	22.74 ± 3.89	24.77 ± 4.30	<0.00*
Height (cm)	164.36 ± 7.91	163.52 ± 6.15	163.84 ± 7.0	0.705
Weight (kg)	64.70 ± 7.78	60.6 ± 8.99	62.11 ± 8.69	0.027*
Waist circ (cm)	74.0 ± 5.22	71.94 ± 6.54	72.91 ± 6.11	0.186
Hip circ (cm)	98.69 ± 4.85	97.34 ± 6.35	97.89 ± 5.65	0.416
Body composition (% fat mass)	23.36 ± 5.88	27.55 ± 7.07	25.46 ± 6.10	0.003*
Handgrip Strength (kg)	20.78 ± 5.97	16.04 ± 11.04	18.41 ± 6.19	0.001*

Table 2.3: Bone Loading History Questionnaire Results

	Strenuous (SE) Group *n*= 35		Nonstrenuous (NSE) Group *n*= 35	
	BLU Hip	**BLU Spine**	**BLU Hip**	**BLU Spine**
Bone Loading Epoch				
Elementary School	386.9 ± 224.73	360.56 ± 210.01	313.35 ± 239.67	300.02 ± 230.42
Jr High School	210.33 ± 126.71*	192.59 ± 111.74**	151.21 ± 84.23	132.65 ± 79.38
High School	256.03 ± 162.73	233.23 ± 153.35	215 ± 122.33	189.73 ± 102.7
Young Adult	458.81 ± 314.05*	459.95 ± 303.49**	167.66 ± 151.48	144.2 ± 125.43
Adult (SE: n=8, NSE: n=3)	144.23 ± 86.42	143.24 ± 90.87	210.64 ±69.39	179.55 ± 61.91
Past Year	91.9 ± 46.7*	84.33 ± 27.55**	39.16 ± 24.01	34.65 ± 20.46
Total	1333.68 ± 715.23*	1281.82 ± 647.95**	865.62 ± 475.96	781.48 ± 431.98
Total Exposure	62.49 ± 29.71	58.56 ± 27.45**	49.63 ± 26.57	44.58 ± 23.91

BLU: Bone Loading Unit
*P<0.05 between groups at the hip, **P<0.05 between groups at the spine
Young adult: 18-29 yrs, Adult: 30-35 yrs, Past year, past 12 months. Total, lifetime-5

Power Analysis

A priori calculations determined that a sample size of 35 per group would provide approximately 80% power at the 5% significance level to detect a medium effect size (Cohen's *W*=0.375) for the difference in MVD between the SE and NSE groups, assuming women will fall into one of 3 categories of MVD (-3,-2,-1 cm), using a 2x3 chi-squared test. This sample size also would provide approximately 87% power to detect a pre-post difference in PFMS within a single exercise group of 4.5 cm H_20, assuming normality and a standard deviation of differences of 8.1, again at the 5% significance level, using a paired *T*-test.

Results

Seventy nulliparous healthy women participated in the study (SE group: *n*=35, NSE group: *n*=35). Subject characteristics are shown in Table 2.2. Compared to the NSE group, SE participants were heavier, had lower % body fat, and higher handgrip strength. All women reported "good" (12.9%, *n*=9), "very good" (51.4%, *n*=36) or "excellent" (35.7%, *n*=25) current health status. Every woman had graduated high school, with many reporting "some college" (48.6%, *n*=34), "completed college" (27.1%, *n*=19), or a "graduate or professional degree" (20%, *n*=14).

Strenuous participants on average participated in CrossFit™ 4.27 ± 0.96 days/week, for the past 22.09 ± 12.29 months. Compared to NSE participants, strenuous participants recorded greater bone loading exposure at both the hip and spine for the junior high school ($P<0.01$), young adult ($P<0.01$), past year ($P<0.01$), and lifetime exposure ($P<0.05$) epochs (Table 2.3).

All study participants completed the POP-Q examination pre- and postexercise. The time from completion of exercise to exam was 5.13 ± 1.27 minutes in the NSE and 6.81 ± 1.34 minutes in the SE group. One SE participant (1.4%) and three NSE participants (4.2%) were unable to contract pelvic floor muscles (verified through vaginal palpation), and therefore PFMS could not be measured. Five participants (2 SE and 3 NSE) felt pain or discomfort upon trial insertion of the pressure sensor, and therefore the research nurse did not conduct the PFMS assessment in these women. Thus, PFMS measures were recorded for 32 SE and 29 NSE participants. When asked "do you regularly perform pelvic floor exercises, such as Kegel exercises?" 68.57% (n=48) reported "no", 17.14% (n=12) reported "yes", and 12.9% (n=9) reported "I don't know". Only one participant reported prolapse symptoms, while 27.7% (n=9) of the SE and 8.57% (n=3) of the NSE participants reported symptoms of urine leakage related to activity, coughing, or sneezing.

Before exercise, there were no significant differences in median VRP (SE: 36.0 cm H_2O (IQR 30.0, 42.6 cm H_2O), NSE: 34.5 cm H_2O (IQR 25.4, 39.8 cm H_2O), P=0.168), MVD (SE: -2 cm (IQR -3, -2 cm), NSE -3 cm (IQR -3, -2 cm); P=0.494) or maximal pelvic floor muscle strength (SE 49.65 cm H_2O (IQR 31.9, 62.05 cm H_2O), NSE: 46.1 cm H_2O (IQR 31.2, 62.9 cm H_2O), P= 0.773) between the SE and NSE groups (Table 2.4). Immediately following exercise, significant increases in MVD were observed in both the SE (P= 0.008) and NSE (P=0.025) groups, indicating marginal decreases in support. VRP significantly decreased postexercise in SE and the NSE groups (P=0.009, P=0.038, respectively). Maximal and mean pelvic floor muscle strength before and after exercise did not differ significantly in either group. The nurse was asked to predict the

Table 2.4: Pelvic Floor Measures: Pre- and Postexercise

	Strenuous (SE) Group		*P* value	Nonstrenuous (NSE) Group		*P* value
	Pre	Post	S Group Pre vs. Post	Pre	Post	NS Group Pre vs. Post
MVD*	-2.0 -3, -2	-2.0 -3, -2	0.008*	-3.0 -3, -2	-2.0 -3, -2	0.025*
VRP** (cmH_2O) SE = 22, NSE = 29)	38.15 ± 10.20	34.99 ± 8.26	0.005*	30.68 ±13.70	29.15± 14.09	0.255
Max PFMS (cmH_2O)	51.12 ± 22.79	47.97 ± 20.34	0.200	49.78 ± 24.62	48.09 ± 22.29	0.511
Mean PFMS (cmH_2O)	45.04 ± 22.02	43.48 ± 20.47	0.503	45.68 ± 22.92	43.28 ± 20.59	0.354

** MVD: Median, Q1, Q3; ** VRP, PFMS: Mean ± SD*
MVD: Maximal vaginal descent (possible values -3 to +3)
VRP: Vaginal resting pressure
PFMS: Pelvic floor muscle strength

group status after completing each participant's POP-Q and pelvic floor muscle strength assessment, and correctly predicted the group assignment in 51.4% of participants (SE, 54.3%, NSE, 48.6%).

Discussion

Strenuous exercise could, in theory, worsen vaginal support by damaging pelvic floor support structure, or improve vaginal support by improving strength overall. We hypothesized that women who habitually performed strenuous activities, because of overall greater strength would have better vaginal support and have higher pelvic floor muscle strength compared to women engaging in less strenuous activities. However, we found no differences in MVD or pelvic floor muscle strength between strenuous and nonstrenuous exercisers before exercise, despite the fact that there were significant differences in long-term habitual strenuous physical activity (indicated by higher BLHQ scores), body composition, and strength measures between groups.

The similarity in pelvic floor muscle strength between groups before exercise suggest that general muscle strengthening through exercise training is not specific to the pelvic floor muscles, supporting the notion of training specificity for muscular development. Another research group also found that nulliparous athletes did not have higher pelvic floor muscle strength compared to nonathletes. In fact, in that study, nulliparous volleyball and basketball athletes had significantly lower average perineal pressure than nonathletes (Borin, Nunes, & Guirro, 2013). Our hypothesis of expected differences in MVD between groups was driven by previous research that demonstrated that on MRI, the width and cross-sectional area of the puborectalis and the levator ani muscles were significantly higher in 10 nulliparous elite athletes compared to aged-matched nonathletic women (Kruger, Murphy, & Heap, 2005). These cross-sectional results suggest that there may be some degree of hypertrophy of the pelvic floor muscles among athletes compared to the nonathletes, yet this difference in muscularity does not appear to confer superior vaginal support among the athletes.

We hypothesized that MVD would increase, indicating a decrease in support, following a strenuous but typical CrossFit™ exercise session for the SE group. Our results indicated that the acute impact of exercise increased MVD for both the SE and NSE groups. This decrease in support was relatively small; postexercise MVD values in both groups were within the normal range of support, as vaginal descent never reached the level of the hymen. The increase in MVD did not exceed 1 cm in any participant, that is, there were no instances of women changing from an MVD of -3 cm to ≥ -1 cm pre- to postexercise (Figure 2.1). We examined participants shortly after exercise so it is unknown how long the slight changes in MVD and vaginal resting pressure were maintained following exercise.

Others have demonstrated changes in pelvic floor support after activity among study populations different from ours. Symptomatic women reported worsening sensation of POP following prolonged periods of standing and lifting (Sung, Clark, Sokol, Rardin & Myers, 2007), indicating that fatigue may contribute to reduced pelvic support. Women with POP demonstrated worse pelvic floor support after a bout of physical activity (Ali-Ross, Smith, & Hosker, 2008). Nulliparous paratrooper military recruits who routinely experienced forceful landings were more likely to have stage-II POP compared to military recruits who performed basic training only (Larsen & Yavorek, 2007). These authors suggested that the added strain of impact during landing resulted in reduced pelvic support among the female paratroopers. Yet, it is possible that increases in intra-abdominal pressure during less severe repeated impact may cause cocontraction of the abdominal and pelvic floor muscles, thus ultimately improving their function (Kruger, Murphy, & Heap, 2005).

Vaginal resting pressure before exercise was similar in both groups, and decreased significantly after exercise in both groups, despite the differences in exercise difficulty. Another study showed no change in vaginal resting pressure in nulliparous women with mild SUI after completing a strenuous bout of exercise, as measured by a fiberoptic microtip transducer connected to a balloon catheter (Ree, Nygaard, & Bo, 2007). Vaginal resting pressure has been identified as an indicator of muscular closing of

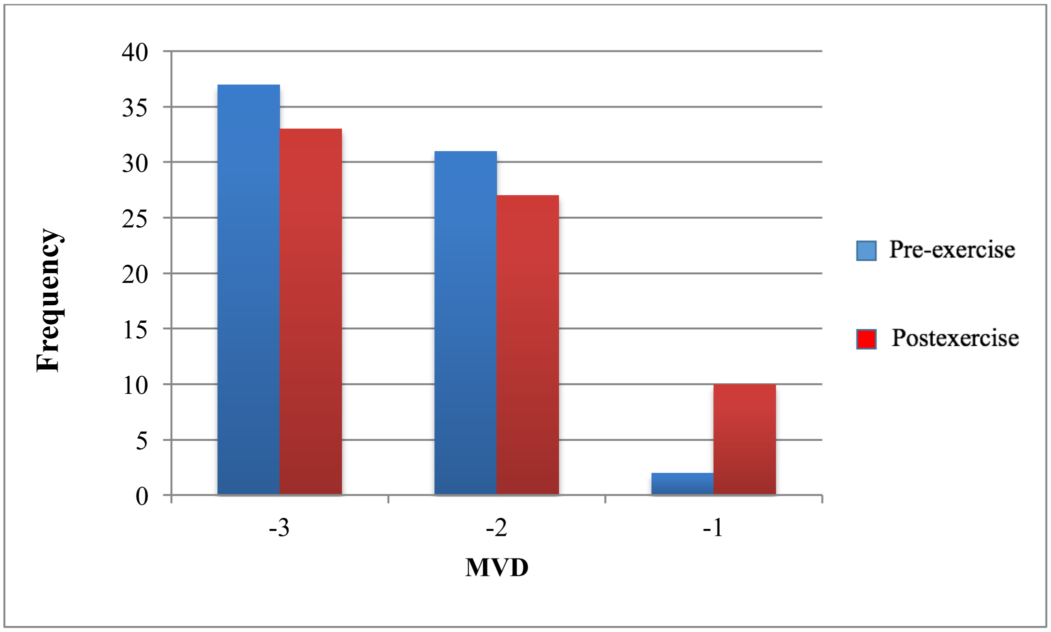


Figure 2.1: Pre- and Postexercise MVD Frequency

the levator hiatus, and low vaginal resting pressure was found to produce the highest odds ratio for POP when combined with low pelvic floor muscle strength in women with stage-≥ II POP (Brækken et al., 2009).

We found no significant change in pelvic floor muscle strength after activity in either group. Ree et al. (2007), however, observed a 20% decrease in maximal voluntary vaginal contraction pressure after a bout of strenuous physical activity in nulliparous women with mild SUI. We expected a decrease in pelvic floor muscle strength after the 20-minute CrossFit™ exercise due to fatigue, but this did not occur. This may reflect increased muscular endurance in women who habitually perform this type of physical activity. Further, nulliparous women with and without SUI likely differ in terms of pelvic floor function.

A strength of this study is the demonstrated differences in physical activity habitually performed by the two groups of women in this study, confirmed by self-reported physical activity status, weight, body composition, and handgrip strength measures. The exercise performed by the SE and NSE groups during testing differed in intensity, but not duration.

Limitations

The study is limited by the fact that strenuous physical activity was represented through women who participate in CrossFit™. There are many other types of strenuous activity, such as competitive athletics, strenuous occupational and household/home tasks, and recreational activities that were not studied in this sample. The research nurse was not blinded to pre- and postactivity status, but she was blinded to the activity women did between tests. The results are not generalizable to other populations, such as parous women or older women.

Conclusions

In the resting condition, no significant differences in vaginal support were observed between SE and NSE women. After a typical exercise bout, vaginal support decreased slightly in both SE and NSE women and vaginal resting pressure decreased only in SE women, suggesting potentially greater muscle fatigue after Crossfit™. However, based on pre-exercise measures, chronic strenuous exercise demonstrated neither beneficial nor deleterious effects on pelvic floor strength or support. While SE women had greater handgrip strength and more favorable body composition than NSE women, pelvic floor muscle strength was not significantly greater, suggesting that targeted pelvic floor muscle strengthening, rather than general muscle fitness, is needed to maximize pelvic floor muscle strength.

CHAPTER 3

CAN A MULITVARIABLE MODEL PREDICT PELVIC FLOOR MUSCLE STRENGTH IN HEALTHY NULLIPAROUS WOMEN?

Abstract

Pelvic floor muscle strength (PFMS) is related to pelvic floor health; it can feel invasive to women and is difficult to measure. Due to the discomfort of a pelvic exam, required for the direct assessment of PFMS, and lack of accessibility to manometry, a prediction equation for PFMS would provide clinicians, health educators, and patients with the ability to identify PMFS and identify PFM laxity or weakness.

Our goal was to develop two pilot prediction equations through multiple regression to predict pelvic floor strength for women who participate in strenuous exercise (SE) and for women who do not do strenuous exercise (NSE), to include waist circumference, body composition, straining to defecate, caffeine consumption, bone loading physical activity in junior high and high school years, isometric upper and lower body strength in the equations. It is expected that elbow and knee isometric strength (flexion and extension MVC in N/m) will be significant predictors of pelvic floor strength as measured by the maximal PFMS, when adjusting for potential confounders.

Healthy nulliparous women ages 18-35 yrs who were habitual SE or NSE exercisers were recruited for the study. Anthropometric measures were assessed using standardized procedures. Body composition was assessed through a Bod Pod. Self-report questionnaires were used to identify (1) caffeine consumption through a healthy history questionnaire, (2) loads applied to the hip and spine through the Bone Loading History Questionnaire (BLHQ) (Dolan, Williams, Ainsworth, & Shaw, 2006), (3) straining to defecate through the Epidemiology of Prolapse and Incontinence Questionnaire (EPIQ). Isometric strength testing was assessed through a Biodex Isokinetic strength measurement device (Biodex Medical Systems, Inc., Shirley, NY). PFMS was assessed

though a Peritron vaginal analysis: A multiple regression was used to identify potential predictors of PFMS.

No significant predictors of PFMS were identified. We concluded that PFMS is a unique measure that cannot be successfully predicted through the anthropometric, behavioral, or physiologic variables that were selected. It cannot be assumed that those with high arm or leg strength will have high PFMS.

Introduction

Pelvic floor muscle strength (PFMS) provides an index of pelvic floor health. Pelvic floor muscle laxity can contribute to urinary and fecal incontinence, pelvic organ prolapse (POP), and can negatively impact sexual function. Weakness in pelvic floor musculature has been widely associated with urinary incontinence (UI), and contradictory results show a potential relationship with weak pelvic floor muscles and the presence of POP (Brækken, et al., 2009; Nygaard, Bradley, & Brandt, 2004). Different modes of measurement to evaluate PFMS have been recommended and used in clinical and research settings, including palpation (e.g,. Brinks test, Oxford grading system), vaginal contraction pressure through a pressure transducer (e.g., manometer, dynamometer), magnitude of contraction (electromyography), and imaging tools (e.g., magnetic resonance imaging (MRI), and ultrasound). A PFMS test is a clinical assessment which seeks to identify pelvic floor muscle strength through measures of pressure during isometric contraction using tactile feedback through palpation or through the use of a more objective measurement through a perineometer. While this information can be beneficial to the clinician and the patient, PFMS testing is not standard practice in an annual gynecologic exam.

In 1984, Kegal identified that the proper movement of PFM during contraction is a squeeze around the pelvic openings and an inward lift. A vaginal contraction is largely isometric, with a small concentric component during the superior movement of the hymen. Pelvic floor muscles, such as the levator ani including the pubocoxygeus and iliocoxygeus, respond to an exercise stimulus in a similar manner to skeletal muscle, by increasing muscle strength and myogenic tone (Bø, 2000). A recent review found that PFMS exercises including modalities with or without biofeedback including Kegal contractions, vaginal electrical stimulation, and magnetic stimulation, strengthened pelvic floor musculature and provided improvement in symptoms in stress urinary incontinence (SUI) (Bø, 2000). These conclusions were also mirrored in results from a similar review examining Urge urinary incontinence (UUI) (Greer, Smith, & Arya, 2012). Pelvic floor muscle strength training is recommended to reduce urinary incontinence, and often is addressed by a medical practitioner to women in the postpartum period and to older women (Sampselle, 1990; Samuelsson, Victor, & Svärdsudd K. 2000; Thompson, O'Sullivan, Briffa, & Neumann, 2006). Pelvic floor muscle strength training is more likely to be evaluated and discussed pre- and postpartum due to the decreases in strength in the PFMs following vaginal delivery (Baytur, Deveci, Uyar, Ozcakir, Kizilkaya, & Caglar, 2005).

Very little is known about PFMS in nulliparous women as it relates to pelvic floor health. Recent research has identified that women who regularly participated in CrossFit® for the previous 6 months had significantly higher upper and lower body strength, but did not demonstrate higher PMFS compared to nonstrenuous exercisers

(Middlekauff, Egger, Nygaard, & Shaw, 2016). Many factors contribute to acute and chronic pelvic floor function. A remedial program such as PFM training (PFMT) with or without biofeedback could then be implemented to strengthen the PFMs and prevent or improve symptoms of dysfunction (Bø, 2000).

Interpreting PFMS is difficult, largely because there is not an established method to identify low or potentially high risk levels of PFMS. Current justifications for a routine pelvic exam include screening for infection, evaluation before the initiation of hormonal contraception, screening for cervical cancer, and early detection of ovarian cancer (Westhoff, Jones, & Guiahi, 2010). Embarrassment, fear of discovery of pathology, and fear of pain have been identified as barriers to seeking care, especially in adolescent females (Millstein, Adler, & Irwin, 1984). Adding an additional PFMS test to a routine pelvic exam is not ideal. Due to the discomfort and aversion to a vaginal exam, the cost associated and lack of accessibility with mamometry, a prediction equation for PFMS would provide clinicians, health educators, and patients with the ability to identify PMFS and potentially identify PFM laxity or weakness. A vaginal perineometer is a more objective measure of PFMS and is used to identify pressure produced during rest and contracted conditions. A Peritron vaginal perineometer (*Laborie*, Canada) can evaluate the maximal pressure produced, the average pressure produced, and the duration of a vaginal contraction.

Multiple variables have been associated with PMFS, yet there have been no known attempts or successful developments of a prediction equation for PFMS. Researchers have attempted to predict response to pelvic floor muscle training using demographic characteristics, clinical incontinence severity indices, and urodynamic measures, but were unsuccessful in predicting a response by behavioral treatment (Theofrastous et al., 2002). While previous research has focused on predicting a physiologic response to a specific behavioral treatment or intervention, our study seeks to predict PFMS using anthropometric, behavioral, and physiologic variables, specifically in nulliparous women. We have identified variables that demonstrate biologic plausibility as potential predictors of PFMS, including (1) waist circumference, due to the increased weight of the abdomen chronically elongating and weakening the myofibrils of the pelvic floor muscles; (2) body composition, due to the increased body fat mass; (3) straining to defecate, due to chronic increases in intra-abdominal pressure; (4) caffeine consumption, due to increased ability to perform a pelvic contraction (Henderson, Wang, Egger, Masters, & Nygaard, 2013); (5) strenuous physical activity in Jr. high and high school years, due to the identification of increased odds ratio of incurring pelvic dysfunction later in life with high physical activity in teen years; and (6) upper and lower body strength, due to a total body-strengthening effect, potentially predicting PFMS.

Women perform a wide variety of physical activity, and the magnitude of intra-abdominal pressure varies significantly by the type of activity performed. A chronic increase in intra-abdominal pressure has been proposed as a mechanism for pelvic laxity due to chronic pressure elongating the myofibrils of the levator ani, causing eventual laxity and distension. Physical activity mode plays a large role in intra-abdominal pressure, and the type of physical activity habitually performed may produce differences in the outcome measure of pelvic floor muscle strength. Due to the wide variations in the types of physical activity that women habitually perform, the exploratory nature of this analysis may benefit from examining two samples of healthy nulliparous women who differ by physical activity status. We sought to develop two pilot prediction equations to predict pelvic floor muscle strength in women who participate in strenuous exercise (SE) and for women who do not perform strenuous exercise (NSE), using multiple regressions. It is expected that elbow and knee isometric strength (flexion and extension MVC in N/m) will be significant predictors of pelvic floor strength as measured by the maximal PFMS.

Significance of the Study

Pelvic floor strength, rather than solely relying on pelvic symptoms, may provide significant insights into the function of the pelvic floor, and could help to provide objective outcomes in research and clinical application. No known study has attempted to predict PFMS in nulliparous women. Previous work has shown that predicting pelvic floor function has been difficult, despite several variables being considered (Theofrastous, Wyman, Bump, McClish, Elser, Bland, & Fantl, 2002). Previous research has focused on parous women, and the pathogenesis of pelvic dysfunction may be different in nulliparous women. We propose that muscular fitness, body habitus, and other reasonable factors related to intra-abdominal pressure and strengthening of pelvic musculature, may predict PFMS in women who have not yet experienced childbirth. The development of two pilot prediction equations, one equation for strenuous exercisers and one for nonstrenuous exercisers, may provide women with a more desirable option by allowing them to perform a simple test battery instead of undergoing a pelvic exam. If the evaluation of the regression equation is shown to be effective through cross-validation, the prediction of pelvic floor strength may identify women who are at increased risk of developing a pelvic floor disorder so that preventive measures or therapeutic interventions can be considered.

Methods

Healthy women ages 18-35 yrs were recruited throughout the Salt Lake City, Utah community through printed advertisements and by word of mouth. All women were free of musculoskeletal injury for the past 6 months, nonsmoking, previously experienced at least one pelvic exam, and were weight stable for the past six months. Women were recruited for one of two specific groups by physical activity level, including habitual participation in (1) strenuous or (2) nonstrenuous exercise. The minimum criteria for participation in the strenuous exercise group (SE) included women who participated at least 3 times a week for a minimum of 6 months in CrossFit™. Women recruited for the nonstrenuous exercise group (NSE) did not habitually perform weight lifting or exercise with an impact component. All study documents were approved through the University of Utah Institutional Review Board prior to recruitment. All participants signed informed consent documents prior to participation in the study.

Self-Report Questionnaires

Caffeine Consumption

To address habitual caffeine consumption, a health history questionnaire was administered and asked the question "In the last three months, about how often did you drink a cup of coffee, tea, or caffeinated soft drink?" with the available responses: (0) Never or less than once a month, (1) At least monthly, but not as often as every day, (2) One to three times per day, (3) More than three times per day. These values were used for descriptive measures and as an independent variable in the prediction equation.

Straining to Defecate

The Epidemiology of Prolapse and Incontinence Questionnaire (EPIQ) was administered to identify symptoms of pelvic floor disorders. The EPIQ has been validated in a similar population for women who were not seeking care for pelvic floor disorders (Lukacz, Lawrence, Buckwalter, et al. 2005). To address the variable straining to defecate, the question "do you ever have difficulty having a bowel movement," was asked. With 3 follow up questions, inquiring about frequency, "How often do you have difficulty having a bowel movement?", degree of bothersome symptom, "How much are you bothered by difficulty having a bowel movement?" addressed through a visual analog scale, and the duration of the symptom "For how long has this difficulty having a bowel movement been a problem?"

Bone Loading Exposure

The Bone Loading History Questionnaire (BLHQ) was administered to assess loads applied to the hip and spine (Dolan, Williams, Ainsworth, & Shaw, 2006), which demonstrated reliability in healthy premenopausal women (self-reported spine loading, r=0.89, self-reported hip loading r=0.92). This questionnaire was used to calculate bone loading exposure as a proxy for strenuous exercise, in the specific age epochs of junior high (3 years) and high school (4 years) years at the hip and spine. These values were used as independent variables in the prediction equation and have been described by group elsewhere (Middlekauff, Egger, Nygaard, & Shaw, 2015, unpublished manuscript).

Anthropometric Measures

Waist circumference was measured through a tension-regulated tape measure, confirmed through two trials, and recorded to the nearest 0.5 in, as recommended by the American College of Sports Medicine (ACSM, 2013). Body composition was evaluated by Bod Pod body composition measurement system (Cosmed Inc., Concord, CA), which has been shown to be a valid and reliable measure of body composition when compared to hydrostatic weighing in healthy adults (McCrory, Gomez, Bernauer, & Mole, 1995). Measures of waist circumference in cm and body composition in kg of lean mass were included as independent measures. These anthropometric measures were used in the regression equations to predict pelvic floor muscle strength.

Strength Measures

Participants performed isometric elbow and knee flexion and extension strength tests on a Biodex isokinetic dynamometer (Biodex Medical Systems, Inc., Shirley, NY). Isometric strength was chosen to mirror the type of contraction performed during PFMS assessment. Maximal voluntary contraction (MVC) was assessed at the elbow and knee at 0deg/sec at 90 degrees of flexion, for both flexion and extension MVC at each joint. The dominant limb performed 3 trials using an alternating agonist /antagonist contraction for a total of 6 contractions for each limb. Each MVC lasted 10 seconds per trial, followed by a 45-second rest. The sum of upper body flexion and extension (N/m) was used in analysis, and similarly, the sum of lower body flexion and extension (N/m) was used as independent variables in the prediction equation.

Pelvic Floor Muscle Strength Test

Participants experienced a PFMS test, using a Peritron 9300 V Vaginal Perineometer (*Laborie*, Canada). In a private enclosed exam room, a certified research nurse assessed the participants. Each participant was asked to void her bladder prior to beginning the exam. Palpation was used to confirm that participants could successfully contract their pelvic floor muscles. For those who were unable to contract their pelvic floor muscles, a pressure sensor was not used due to the reasonable assumption that the contraction pressure would be zero. The perineometer was used to assess maximal PFMS. Each participant that correctly demonstrated pelvic floor muscle contraction was asked to completely relax after the pressure sensor was inserted. The research nurse instructed the participant to contract their PFMs maximally, recording the maximal contraction pressure after each trial for a total of 3 trials. PFMS is recorded in standard pressure units of cm/H20 by the Peritron perineometer, which is defined as the pressure exerted by a column of water of 1 cm in height at 4 °C (temperature of maximum density) at the standard acceleration of gravity. The values from the maximal PFMS test by group were used as the outcome (dependent) variable in the prediction equations.

Data Analysis

All statistical analyses were made using Stata version 13.1 (StataCorp, 2013. *Stata Statistical Software,* College Station, TX). A visual assessment using histograms and box plots was used to identify the normality of the data for PFMS. Means and standard deviations were used to provide descriptive statistics of the sample population. Independent *T*-tests identified potential differences between groups for independent and dependent variables. A correlation matrix and a variance inflation factor test served to identify any variables that may have violated a multicollinearity assumption prior to conducting regression analyses (mean VIF = 1.87).

To determine the best predictors of PFMS, a multiple linear regression was performed in each group. To predict the outcome (dependent) measure PFMS for the SE and NSE groups, the independent variables (1) waist circumference in cm, (2) body composition in lbs of lean mass, (3) straining to defecate as dichotomous "yes" or "no", (4) caffeine consumption on a categorical scale of 0 to 4, (5) the sum of bone loading exposure for the spine and hip in Jr High in BLU, (6) the sum of bone loading exposure for the spine and hip in High School in BLU, (7) the sum of isometric upper body strength in N/m, and (8) the sum of isometric lower body strength in N/m were entered simultaneously into the regression model. The initial model included eight variables above variables and this was followed by stepwise regression to seek the most parsimonious model. To investigate the effect of significant variables, a Directed Acyclic Graph (DAG) (Appendix E) was consulted to interpret the results of the prediction model.

Results

Seventy nulliparous healthy women participated in the study (SE group: n=35, NSE group: n=35). The subject characteristics are reported in Table 3.1. The SE participants were older, heavier, and had significantly lower body fat % compared to their

Table 3.1: Subject Characteristics

	SE Group (*n*=35)	**NSE Group (*n*=35)**	**Total (*n*=70)**
Age (yr)	26.8 ± 3.79*	22.74 ± 3.89	24.77 ± 4.30
Height (cm)	164.36 ± 7.91	163.52 ± 6.15	163.84 ± 6.99
Weight (kg)	64.70 ± 7.78*	60.6 ± 8.99	62.11 ± 8.69
Waist Circumference (cm)	74.0 ± 5.22	71.94 ± 6.54	72.91 ± 6.11
Body composition % fat-free mass	76.64 ± 5.88*	72.45 ± 5.66	74.54 ± 6.10

**P<0.05 between groups*

NSE counterparts. Waist circumference and PFMS results showed no difference between groups (*P*=0.1855, and *P*=0.825, respectively.)

Straining to Defecate

When asked: “do you ever have difficulty having a bowel movement,” 41.43% of the sample responded with “yes,” a 2-tailed independent *T*-test identified that there was no significant difference between groups (*P*=0.09). Those who reported difficulty were then asked to report their symptom frequency. Of the 41.43% who initially answered “yes,” 12.5% experienced difficulty less than once per year, 46.88% more than once per year, but less than once per month, 31.25% more than once per month, but less than once per week, 9.38% at least once per week, but not every day. Regarding duration of the difficulty, 25% responded that they experienced difficulty for less than a year, 37.5% 1 to 5 years, 15.62% 6 to 10 years, and 21.88% experienced difficulty having a bowel movement for more than 10 years.

Caffeine Consumption

Responses to the question "In the last three months, about how often did you drink a cup of coffee, tea, or caffeinated soft drink?" with the available responses: (0) Never or less than once a month, (1) At least monthly, but not as often as every day, (2) One to three times per day, and (3) More than three times per day, ranged from 0-2. 15.71% of the sample responded as "0", 28.57% responded as "1," and 55.71% responded as "2." Responses differed significantly by group, indicating slightly higher caffeine consumption among SE women compared to NSE women (Mean ± SD: NSE: 1.143 ± 0.77, SE: 1.66 ± 0.64, P=0.0034).

Bone Loading Units

Results from the Bone Loading History Questionnaire (BLHQ) in the Jr High and High School years revealed a significant difference between groups during the 3-year time span in Jr High (P=0.0165), but no significant difference was found during the 4-year time span during the High School years (P=0.2016) between groups (Table 3.2). The correlation matrices indicated fairly weak relationships between the outcome variable PFMS and the eight independent predictor variables.

Tables 3.3, 3.4, and 3.5 provide correlation information for the total sample combined (Table 3.3), and for the sample separated by physical activity status (Table 3.4 and 3.5). In the combined sample, the sum of lower body strength had the highest correlation with PFMS (r=0.227), which continued to be the highest correlation in nonstrenuous exercisers NSE (r=0.383), however in the strenuous exercise group, bone loading in high school had the highest correlation with PFMS (r=0.242).

Table 3.2: Isometric Upper and Lower Body Strength, PFMS and History of Strenuous Activity

	SE Group (*n*=35)	**NSE Group (*n*=35)**	**Total (*n*=70)**
Elbow Isometric MVC (N/m)			
Sum of Flexion & Extension	90.14 ± 18.10*	67.02 ± 15.82	78.58 ± 20.5
Knee Isometric MVC (N/m)			
Sum of Flexion & Extension	283.99 ± 68.37*	230.26 ± 59.66	257.12 ± 69.21
PFMS (cm/H_20)	51.12 ± 22.79	49.78 ± 24.63	50.48 ± 23.29
Sum BLU Jr.High	402.92 ± 236.24*	283.86 ± 162.18	343.39 ± 209.89
Sum BLU High School	489.26 ± 315.30	405.10 ± 222.89	447.18 ± 274.34

**P<0.05 between groups*

Discussion

Our intention in this study was to develop two pilot prediction equations through multiple regression to predict PFMS in women who participate in either strenuous exercise (SE) or in nonstrenuous exercise (NSE). The results indicated nonsignificant regression equations for either strenuous or nonstrenuous groups (Table 3.6). No group of variables identified as biologically relevant potential predictors for PFMS were identified as successful predictors of PFMS. Only lower body strength produced a significant correlation with PFMS in the NSE group (Table 3.5), which was not a significant predictor of PFMS when examined in one of the three the regression models for the NSE group (Table 3.6). Additionally, we did not find any significant correlations between any of the independent variables (1) waist circumference, (2) body composition, (3) straining to defecate, (4) caffeine consumption, (5) bone loading exposure for the spine and hip in Jr High in BLU (6) bone loading exposure for the spine and hip in High School in BLU, (7) isometric upper body (sum of flexion and extension) in N/m, and (8)

Table 3.3: Correlation Matrix for Total Sample

	PFMS	Waist Circumference	Lean Mass	Strain to Defecate	Caffeine	Sum Jr High BLU	Sum HS BLU	Sum Upper Body	Sum Lower Body
PFMS (cm/$H_2$0)	1.000								
Waist Circumference (cm)	0.2420	1.000							
Lean Mass (%)	-0.2828	-0.7543	1.000						
Strain to Defecate	0.0622	0.0853	-0.2245	1.000					
Caffeine	-0.1159	0.1597	-0.1998	0.3077	1.000				
Sum Jr High BLU	-0.1037	-0.0557	0.0538	-0.0035	-0.2374	1.0000			
Sum HS BLU	0.0964	-0.0176	0.1122	0.1629	-0.3106	0.6129	1.0000		
Sum Upper Body (N/m)	0.2903	0.0335	0.1544	-0.5775	-0.1926	0.0202	0.1034	1.0000	
Sum Lower Body (N/m)	0.3830*	0.0280	-0.1090	0.0083	-0.0812	0.2555	0.2652	0.5504	1.000

Table 3.4: Correlation Matrix for Nonstrenuous Exercisers

	PFMS	Waist Circumference	Lean Mass	Strain to Defecate	Caffeine	Sum Jr High BLU	Sum HS BLU	Sum Upper Body	Sum Lower Body
PFMS (cm/$H_2$0)	1.000								
Waist Circumference (cm)	0.1381	1.000							
Lean Mass (%)	-0.1585	-0.5099	1.000						
Strain to Defecate	0.0608	0.0437	-0.0468	1.000					
Caffeine	-0.0050	0.2456	-0.0983	0.1324	1.000				
Sum Jr High BLU	0.09016	0.0700	0.2062	0.1661	0.1189	1.0000			
Sum HS BLU	0.1839	0.1661	0.2169	0.1525	-0.0485	0.5935	1.0000		
Sum Upper Body (N/m)	0.1538	0.3294	0.1328	-0.0652	0.1434	0.1566	0.2040	1.0000	
Sum Lower Body (N/m)	0.2271	0.3338	-0.0173	-0.0530	0.1726	0.2422	0.3196	0.6817	1.000

Table 3.5: Correlation Matrix for Strenuous Exercisers

	PFMS	Waist Circumference	Lean Mass	Strain to Defecate	Caffeine	Sum Jr High BLU	Sum HS BLU	Sum Upper Body	Sum Lower Body
PFMS (cm/H_20)	1.000								
Waist Circumference (cm)	0.0013	1.000							
Lean Mass (%)	-0.0870	-0.4900	1.000						
Strain to Defecate	0.0513	-0.0156	-0.0127	1.000					
Caffeine	0.1105	0.1277	-0.2244	-0.1639	1.000				
Sum Jr High BLU	0.1989	-0.0110	0.2960	0.2990	0.1021	1.0000			
Sum HS BLU	0.2422	0.2011	0.2827	0.2564	-0.0777	0.5614	1.0000		
Sum Upper Body (N/m)	0.0584	0.6190	-0.3295	0.1003	-0.0694	-0.0563	0.1701	1.0000	
Sum Lower Body (N/m)	0.1240	0.4735	-0.2776	-0.0595	0.1818	0.0243	0.2070	0.7267	1.000

$P<0.05$

Table 3.6: Regression Models

	R^2	Adjusted R^2	Std Error of the Estimate	F change	df1	df2	Sig. F
Model 1 NSE	0.3484	-0.0137	24.374	0.96	10	18	0.5056
Model 2 SE	0.1411	-0.1576	24.517	0.47	8	23	0.8630
Model 3 Stepwise NSE	0.247	0.156	22.24	2.73	3	25	0.065
Model 4 Stepwise SE	0.059	0.027	22.47	1.87	1	30	0.182
Model 5 NSE with Past Yr BLU	0.48	0.235	21.57	1.96	9	19	0.105

isometric lower body (sum of flexion and extension) and pelvic floor muscle strength in the SE group. Due to the significance of lower body strength in the NSE group, further investigation was needed to identify the relationship of lower body strength to PFMS. A stepwise regression was used to create a more parsimonious equation (Table 3.5, model 3 and 4) for NSE and SE groups, which were also found to be nonsignificant. The DAG was used to interpret the results from the initial prediction models, which identified a potentially missing variable of past year physical activity for the NSE group. The regression model included the eight initial independent variables, but added one additional variable "past year BLU" from the BLHQ to account for the physical activity exposure experienced in the previous 12 months. The results from model 6, including the additional variable, also produced a nonsignificant regression equation.

Lower body strength was a significant predictor of pelvic floor muscle strength in the NSE group. We hypothesized that lower and upper body strength would be significant predictors of PFMS. Previous research from MRI and ultrasound data collected in elite nulliparous athletes indicated an increase in the area of the levator ani, thickening of the pubovisceral muscle diameter, and increased distensibility of these muscles during Valsalva, when compared to their nonathletic counterparts (Kruger, Deitz, & Murphy, 2007; Kruger, Murphy, & Heap, 2005). It is well known that the strength of a muscle is proportional to its cross-sectional area. Strength training in skeletal muscle is necessary to produce the desired strengthening adaptation (Beachle & Earle, 2008). Similarly in pelvic floor muscles, a strengthening stimulus through purposeful contraction of the pelvic floor musculature has been shown to be effective in reducing SUI symptoms and increasing PFMS (Bo, 2007). Previous research examining predictors of skeletal muscle of young healthy women (20-39yr) found that 1) smoking status, 2) physical activity, 3) fat mass, and 4) total body water were significant independent predictors of skeletal muscle mass (Limpawattana, Assantachai, Krairit, et al. 2015).

When examining the predictors of POP in parous women, physical activity was not significant, although body mass index, socioeconomic status, heavy occupational work, anal sphincter lacerations, and PFM function were independently associated (Brækken, Majida, Ellstro¨m Engh, Holme, & Bø, 2009). Previous attempts to predict response to pelvic floor muscle training using demographic characteristics, clinical incontinence severity indices, and urodynamic measures were unsuccessful in predicting a response (Theofrastous et al., 2002). While others have found it difficult to predict pelvic floor outcomes in parous women, we hypothesized that predicting PFMS in nulliparous women would yield significant outcomes and benefit clinicians. Yet our results produced similar nonsignificant findings when using PFMS as the dependent variable. Perhaps PFMS is a unique measure that cannot be predicted by previous physical activity, current measures of body habitus and composition, current behaviors relating to caffeine consumption or intra-abdominal strain due to constipation, or current body strength. Given that skeletal muscle strength variables tend to significantly correlate with each other (upper and lower body strength: r=0.6817 in the combined sample, Table 3.4), we anticipated that the appendicular and pelvic floor strength measures would be similarly related, especially when performing a similar static (isometric) contraction. The results indicated the measures of upper and lower body strength were only moderately positively correlated with PFMS or not correlated at all, which was not an expected outcome.

The correlation matrices indicated slightly different relationships between the eight independent variables and the outcome measure of PFMS by SE and NSE group status, but none of these relationships were remarkable. While this finding provides some evidence to consider the role of physical activity on PFMS in future research, it may be that these factors become more important in pelvic floor health after childbirth.

Bone loading history as a proxy for strenuous activity, especially during physical development and maturation in junior high school years, did not contribute to PFMS. High-volume and high-intensity exercise during this time frame, when such exposure could be detrimental to connective tissues, could be a potential explanatory variable in pelvic floor dysfunction later in life (Nygaard, Shaw, Bardsley, & Egger, 2014). The results from this study did not identity a negative influence of bone loading during adolescence as a contributor to PFMS in healthy nulliparous women. The women in the NSE group had significantly lower bone loading activity in adolescence, as noted by the Jr High School epoch. We do not have qualitative data to provide context to this difference in quantity of physical activity during this time period. The NSE women may have performed less bone loading activity in their early years due to a connective tissue injury which led to performing lower intensity physical activity patterns later in life as well.

After examining the results, one may question whether PFMS is an important measure of pelvic floor function in healthy asymptomatic women. Is it possible to identify a threshold level of PFMS required to avoid symptoms? Others have produced contradictory results for reduced PFMS and presence of POP (Brækken et al., 2009; Nygaard, Bradley, & Brandt, 2004), noting positive and negative results for decreased

PFMS with the presence of POP. The variables that were selected as potential predictors of pelvic floor muscle strength had demonstrated biologic plausibility, and had indicated face validity from previous research. The five models examined produced nonsignificant results. We were unable to produce a regression equation that would benefit clinicians in a manner that would be more beneficial than performing a PFMS test in a focused pelvic exam. The results of this study questions the likelihood that a prediction model could successfully be created. The sum of lower body strength was the only significant correlation with PFMS and it occurred in the nonstrenuous exercisers (r =0.051). Perhaps the result of low correlations with the identified predictors of PFMS point to the unique nature of PFMS. Targeted training of the pelvic floor muscles is necessary to provide the desired strengthening response.

The strengths in this study include well-defined groups who habitually performed markedly different types of physical activity. All participants volunteered for the study, which reduced bias. Participants performed the same types of skeletal muscle contraction when assessing arm, leg, and pelvic floor muscle strength. The validated BLHQ assessed the bone loading exposure and served as a proxy to quantify recent and past strenuous physical activity. One trained clinician performed all of the focused pelvic exams and was blinded to group status.

Limitations

The observations of this study are tempered by the limitations inherent to cross-sectional studies. PFMS was assessed through pressure (cmH_2O), while all other strength measures were expressed in typical values of force (Nm or Kg), which may explain some of the nonsignificant findings. Many of the measures were novel to the population, specifically PFMS and isometric arm and leg strength, and these measures could experience change in results after a familiarization period. Yet it was infeasible to provide all participants with practice sessions of all examinations in order to provide testing familiarization, which has been shown to influence measures of muscular strength in particular (Sedliak, Haverinen, & Hakkinen, 2011).

Every effort was made to identify the reasonable potential predictors of pelvic floor muscle strength. While genetic factors are a known contributor to pelvic floor dysfunction, genetic testing was not included in this study because we wanted to identify a battery of simple tests that could be done to identify women who are at risk of low pelvic floor muscle strength.

The sample size is relatively low compared to other studies that attempted to create prediction equations (Yang, Yang, Huang, & Tzeng, 2013), and a retrospective power analysis reveals that this study may be underpowered to detect a significant relationship between the independent variables and PFMS.

Conclusions

Pelvic floor muscle strength assessed by vaginal Perineometer was unable to be predicted through anthropometric, behavioral, historical physical activity loads, and leg and arm muscular strength variables in healthy, nulliparous women. If pelvic floor muscle strength is predictable through a series of variables, we did not identify the correct combination of variables. The lack of predictability in PFMS may indicate that PFMS is a unique measure that cannot be assumed to be higher or lower in women who perform different types of physical activity, and requires direct examination to produce valid and reliable results.

CHAPTER 4

CONCLUSION

Introduction

Pelvic floor function has been widely studied in parous women, yet nulliparous women still experience pelvic dysfunction (Durnea, Khashan, Kenny, Tabirca, & O'Reilly, 2014). The aetiology of POP is considered to be multifactorial (Brækken et al., 2009). While vaginal delivery is a known contributing factor in the development of POP, the pathogenesis of POP is largely unknown in nulliparous women. Current and previous strenuous physical activity has been proposed as a potential explanatory variable as to the development of incontinence and POP due to high intra-abdominal pressures experienced during lifting and landing (Jorgensen, Hein, & Gyntelberg, 1994; Larsen & Yavorek, 2007). The results from our research do not support this conjecture.

The comparison of pelvic floor function in nulliparous women who habitually perform strenuous physical activity to women who do not perform strenuous physical activity produced nonsignificant differences in vaginal resting pressure, maximal PFMS, and MVD. Pelvic floor support and PFMS appear to be similar in the healthy nulliparous women in our study, regardless of their vastly different, habitual physical activity practices. These results were not anticipated and challenged the notion that increased upper and lower body strength training would simultaneously strengthen the pelvic floor muscles through cocontraction and increased intra abdominal pressure.

Previous studies have identified a worsening POP stage after a bout of physical activity in 25% of older women (Ali-Ross, Smith, & Hosker, 2008). Our results examining healthy nulliparous women showed decrease in support with an increase in MVD after acute exercise in both strenuous exercisers and nonstrenuous exercisers. However, this decrease in support as defined by MVD was still considered to be in the range for healthy support. While an acute change in MVD was noted after exercise, the chronic effect of the habitual performance of strenuous physical activity did not produce any deleterious changes in pelvic support, as evidenced by no differences at rest. Maximal PFMS remained unchanged after exercise, regardless of the level of strain experienced in the respective bouts. Others have reported increased pelvic floor muscle fatigue after a long bout of exercise in similarly aged nulliparous women who had UI symptoms during activity (Ree, Nygaard, & Bo, 2007).

Studies examining SUI have proposed that high intensity impact exercise may change the muscular function of the pelvic floor, especially during landing (Bo & Borgen, 2001; Eliasson, Larsson, & Mattsson, 2002; Nygaard, Thompson, Svengalis, & Albright, 1994; Thyssen, Clevin, Olesen, & Lose, 2002). Immediately upon completion of an acute bout of high-intensity or moderate physical activity, both groups of women in the present study did not experience a decrease in pelvic floor muscle strength. This finding is encouraging to women who prefer to perform strenuous physical activity, due to the growing popularity of high-intensity exercise training.

In skeletal muscle physiology it is well understood that a muscle group will respond by producing an adaptation to a specific stimulus that is applied to that muscle group. We have considered the question: Do women who have higher strength, as measured by arm and leg flexion and extension, also have higher PFMS? The evidence from this study does not support this notion. PFMS may be a unique measure that cannot easily be predicted by a series of anthropometric, behavioral, physical activity, or physical strength measures. Pelvic floor strength appears to be a unique measure that cannot easily or practically be predicted from the variables that we have identified from previous research. Based on the present findings, it would be an incorrect assumption to conclude that women who perform strenuous activity resulting in high physical strength and greater fat-free mass would also have high PFMS when compared to their peers who do not do strenuous activity. Future studies should clarify this relationship and identify potential methods to better evaluate and quantify total body strength. Pelvic floor muscle strength in both studies was evaluated through a perionometer that produces an output of pressure in cmH_2O. This pressure unit was compared with appendicular and handgrip strength measures in kg of force. Using the Imperial measurement system, this is the equivalent of comparing pounds per square inch (psi) to pounds (lbs). A recently developed instrumented speculum was designed to measure vaginal contraction pressure in Newtons of force, which could produce a more reasonable comparison to traditional units of body strength (Miller, Ashton-Miller, Perruchini, & DeLancey, 2007).

MRI and ultrasound data collected in elite nulliparous athletes indicated an increase in the area of the levator ani and thickening of the pubovisceral muscle diameter during Valsalva, when compared to their nonathletic counterparts (Kruger, Deitz, & Murphy, 2007; Kruger, Murphy, & Heap, 2005). Our results indicated that high upper body and lower body strength did not produce a reciprocal increased strength in the pelvic floor muscles. This result indicates that pelvic floor muscles do not benefit from total body strengthening and must be purposefully targeted with muscle activation. This supports the training principle of specificity; the training stimulus must be specific to address the desired outcome (Beachle & Earle, 2008). While previous research has shown an increase in area and diameter of pelvic floor muscles, it is unknown if the increased area and diameter resulted in increased PFMS.

If high-intensity exercise during development has a potential to negatively impact pelvic floor health later in life (Nygaard, Shaw, Bardsley, & Egger, 2014), we may be missing an opportunity for intervention during developmental years. The current curriculum of many strength and conditioning certifications (e.g., the Strength and Conditioning Specialist certification (CSCS) through the National Strength and Conditioning Association, 2015) does not include any information or training regarding pelvic floor muscle strength as a component of strength and conditioning training. The field of physical therapy has integrated pelvic floor rehabilitation into a specialty of women's health, which presents a potential opportunity to address PFMS for women of all fitness levels. Many women who participate in high-intensity exercise do not seek care from a physical therapist unless an injury has occurred or symptoms of dysfunction are present. Low PFMS is largely asymptomatic and can lead to symptoms of incontinence and POP if unaddressed. It would be beneficial to address PFMS before symptoms were present. It is unknown if preventative or remedial programs would be beneficial if offered through trained professionals in strength and conditioning (e.g., coaches, personal trainers, strength and conditioning specialists, group fitness instructors, etc.)

Limitations

The women in the study were healthy young nulliparous women. In both studies, strenuous physical activity was represented through women who participate in CrossFit™. It is recognized that there are many other types of strenuous activity, such as competitive athletics, strenuous occupational and household/home remodeling tasks, and recreational activities that were not represented in this sample. These activities may have been represented, but the participants were not further delineated into representative samples of those activities. While this sample is largely homogeneous, it is also heterogeneous by habitual participation in physical activity. While the first study was adequately powered, the sample size in the second study was relatively low to successfully predict a regression equation. While the study was exploratory in nature, this may have explained the lack of significant predictors. When examining factors of pathogenesis, it would be advantageous to use a longitudinal study design. A longitudinal research design was not feasible for the purposes of this study.

Future Research

Many questions regarding pelvic floor muscle strength and the development of POP remain. The relationship between pelvic floor muscle strength and upper and lower body strength is not well understood. There may be a strengthening effect from the intra-abdominal pressure that is raised during lifting activities, however the 1) type of exercise, 2) breathing techniques (e.g. Valsalva maneuver), and 3) magnitude of the load have not been thoroughly explored.

A measure of total body strength does not currently exist. It would be beneficial to have a measure of limb strength and core strength to meaningfully quantify overall body strength in habitual lifters and nonlifters alike. Olympic lifting offers lifts such as the overhead snatch or clean and jerk that include significant muscle mass, and could serve as a proxy for total body strength. However, due to the technical skill involved in those lifts and the high risk of injury they are not a practical measure of strength in participants who do not regularly perform these lifts.

While higher rates of women are participating in high-intensity exercise, it is important to consider the potential deleterious effect later in life. Does high-intensity exercise during development have a negative impact on pelvic floor health after childbirth? It is also unclear is there is a target value for pelvic floor muscle strength. Is high PFMS protective of incurring POP, or any or pelvic floor dysfunction later in life? What is the most important measure of pelvic floor function for clinicians to measure regarding pelvic floor health? Is PFMS a necessary component of a routine pelvic exam? Future research should direct efforts to answering these questions, as this information would fill a gap in the current understanding of POP and PFMS.

APPENDIX A

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE

Physical Activity Readiness Questionnaire (PAR-Q)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before starting to become much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO		
☐	☐	1.	Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by your doctor?
☐	☐	2.	Do you feel pain in your chest when you do physical activity?
☐	☐	3.	In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4.	Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5.	Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
☐	☐	6.	Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	7.	Do you know of any other reason why you should not do physical activity?

If you answered

YES to one or more questions

Talk to your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may able to any activity you want – as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful to you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- Take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- If you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- If you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

Participant Code____

SIGNATURE ____

SIGNATURE OF PARENT________________________________

APPENDIX B

MEDICAL AND DEMOGRAPHIC HISTORY QUESTIONNAIRE

THE UNIVERSITY OF UTAH

MEDICAL AND DEMOGRAPHIC HISTORY QUESTIONNAIRE

We are collecting some information about you so that we can assess factors that may be involved in your physical activity and pelvic floor health. Thank you for your responses!

1. What is your date of birth? __/__/____

2. What was the date of your of your last pelvic exam (or PAP smear)? __/__/____

3. What is the highest grade or year of school that you have completed?
   ☐ Less than high school
   ☐ Completed high school or equivalent
   ☐ Some college/Associate degree
   ☐ Completed 4 years of college
   ☐ Graduate/Professional degree

4. In the last three months, about how often did you drink a cup of coffee, tea, or caffeinated soft drink?
   ☐ Never or less than once a month
   ☐ At least monthly, but not as often as every day.
   ☐ One to three times per day
   ☐ More than three times per day

5. Have you ever been pregnant? ☐ Yes ☐ No (Go to Question 6)
   a. How many Cesarean deliveries have you had? _____(If none, please write "0")
   b. How many vaginal deliveries have you had (over 20 weeks)? ____
      (If none, please write "0")

6. Has a doctor or other health care provider ever told you that you have any of these medical
   conditions? (please check all that apply)
   ☐ High blood pressure
   ☐ Arthritis
   ☐ Diabetes
   ☐ Cancer
   ☐ Chronic cough
   ☐ Heart attack
   Continued: Has a doctor or other health care provider ever told you that you have any of these medical conditions? (please check all that apply)

☐Angina (chest pain)
☐Major depression
☐Seasonal allergies, such as hayfever
☐Sleep apnea
☐Chronic low back pain

7. How many different prescription medications, other than vitamins and hormones, are you currently taking? ____

8. In general, would you say your health is:
☐Excellent ☐Very Good ☐Good ☐Fair ☐Poor

9. Do you regularly experience low back pain? ☐Yes ☐No ☐Don't know

10. In the last three months, about how often did you experience low back pain?
☐Never
☐Less than once a month
☐At least monthly, but not as often as every day
☐At least once per day

11. If you participated in athletics, what was the highest level of competition that you experienced in organized sports?
☐Did not participate
☐Recreational
☐High School
    ☐Junior Varsity
    ☐Varsity
☐Collegiate
☐Semi professional
☐Professional

12. Do you regularly perform pelvic floor exercise? ☐Yes ☐No ☐Don't know

Thank you for completing our questionnaire, your responses are very helpful to us!

APPENDIX C

EPIDEMIOLOGY OF PELVIC ORGAN PROLAPSE AND INCONTINENCE QUESTIONNAIRE

PHYSICAL ACTIVITY AND PELVIC FLOOR DISORDERS Page 1 of 12

Pelvic Floor Health Questionnaire

Participant ID ☐☐☐☐ Visit Date ☐☐-☐☐-☐☐ (Mth Day Year) Site ID ☐☐☐☐☐

These next questions are about problems some women have with their ***bowel and bladder control and female organs.*** Please answer these questions about your CURRENT PROBLEMS, not those that you may have had in the past that resolved through treatment or on their own. If you do not know the exact answer to any of these questions, please estimate the answer. We understand that your habits change with activity, location (work vs home), how much you drink, medications, etc., so please base your answers on an average day.

Some of the questions below use a scale to estimate how much problems bother you. Here is an example of how to answer this type of question.

This is the CORRECT way to complete this survey question:

Place a | on the line below:

Not at all ———|——— Greatly

This is the INCORRECT way to complete this survey question:

Please do not place a line above the line.

Not at all ———————— Greatly

Please do not write in a response.

Moderately

Not at all ———————— Greatly

Please do not use other symbols, long lines, big circles, large X's, etc.

Not at all ———***0 X ✓***——— Greatly

Please do not leave the question blank.

Not at all ———————— Greatly

PHYSICAL ACTIVITY AND PELVIC FLOOR DISORDERS Page 2 of 12

Pelvic Floor Health Questionnaire

1. Do you rush to the bathroom so that you will not have leakage of urine?

☐ Yes continue ☐ No go to question # 2

a. How much are you bothered by the need to rush to the bathroom?

(Please place an "I" on the line.)

Not at all ———————— Greatly

2. During waking hours, how frequently do you need to empty your bladder?

☐ Less than every six hours

☐ Every 5 to 6 hours

☐ Every 3 to 4 hours

☐ Every 1 to 2 hours

☐ More than once per hour

a. How much are you bothered by the frequency with which you must empty your bladder? (Please place an "I" on the line.)

Not at all ———————— Greatly

Remember: Answer these questions based on your CURRENT SYMPTOMS.

PHYSICAL ACTIVITY AND PELVIC FLOOR DISORDERS Page 3 of 12

Pelvic Floor Health Questionnaire

Participant ID ☐☐☐☐

3. Do you awaken during your normal sleeping hours to urinate?

☐ Yes continue ☐ No go to question # 4

a. How many times on average do you need to empty your bladder during sleeping hours?

☐ Once ☐ 2 times ☐ 3 times ☐ 4 times ☐ 5 or more times

b. How much are you bothered by the need to get up at night to empty your bladder? (Please place an "I" on the line.)

Not at all ———————— Greatly

4. Do you experience frequent urination?

☐ Yes continue ☐ No go to question # 5

a. How much are you bothered by frequent urination?

Not at all ———————— Greatly

5. Do you experience urine leakage related to a feeling of urgency?

☐ Yes continue ☐ No go to question # 6

a. How much are you bothered by urine leakage related to a feeling of urgency?

Not at all ———————— Greatly

Remember: Answer these questions based on your CURRENT SYMPTOMS.

PHYSICAL ACTIVITY AND PELVIC FLOOR DISORDERS Page 4 of 12

Pelvic Floor Health Questionnaire

6. Do you experience urine leakage related to activity, coughing, or sneezing?

☐ Yes continue ☐ No go to question # 7

a. How much are you bothered by urine leakage related to activity, coughing, or sneezing?

Not at all ———————— Greatly

7. Do you experience small amounts of urine leakage (drops)?

☐ Yes continue ☐ No go to question # 8

a. How much are you bothered by small amounts of urine leakage (drops)?

Not at all ———————— Greatly

8. Do you experience difficulty emptying your bladder?

☐ Yes continue ☐ No go to question # 9

a. How much are you bothered by difficulty emptying your bladder?

Not at all ———————— Greatly

9. Do you experience pain or discomfort in your lower abdomen or your genital area?

☐ Yes continue ☐ No go to question # 10

a. How much are you bothered by pain or discomfort in your lower abdomen or your genital area?

Not at all ———————— Greatly

Remember: Answer these questions based on your CURRENT SYMPTOMS.

Pelvic Floor Health Questionnaire

Participant ID

If you experience urine leakage, please answer the following questions. Otherwise, go to question 14 on the next page.

10. Has urine leakage affected your:

a. Ability to do household chores (cooking, housecleaning, laundry)?

Not at all ———— Greatly

b. Physical recreation such as walking, swimming, or other exercise?

Not at all ———— Greatly

c. Entertainment activities (movies, concerts, etc.)?

Not at all ———— Greatly

d. Ability to travel by car or bus more than 30 minutes from home?

Not at all ———— Greatly

e. Participating in social activities outside your home?

Not at all ———— Greatly

f. Emotional health (nervousness, depression, anger)?

Not at all ———— Greatly

g. Feeling frustrated?

Not at all ———— Greatly

Remember: Answer these questions based on your CURRENT SYMPTOMS.

Pelvic Floor Health Questionnaire

11. Do you ever wear anything in your vagina such as a pessary or tampon to prevent urine leakage?

☐ Yes ☐ No

12. Do you ever wear panty liners, pads, diapers, or toilet paper, or do you change your undergarments to protect your clothes from urine leakage?

☐ Yes ☐ No

This is the halfway mark! You are doing great. We understand that there are a lot of questions and value your precious time.

13. Have you ever asked a doctor, nurse, or other healthcare professional for help with urine leakage?

☐ Yes ☐ No

14. Have you had any surgeries or procedures to correct urine leakage?

☐ Yes continue ☐ No go to question # 15

a. How many surgeries or procedures have you had to correct urine leakage?

☐ # of surgeries

Some women will experience loss of support that can cause heaviness, pressure or a bulge around their vagina. This is called "pelvic prolapse"—You may have heard it called "cystocele", "rectocele" or "dropped bladder". Please answer each of the following questions about pelvic prolapse to the best of your ability.

We realize that you may have good days and bad days. Please answer these questions based on a typical day.

Remember: Answer these questions based on your CURRENT SYMPTOMS.

Pelvic Floor Health Questionnaire

Participant ID

15. Do you have a sensation that there is a bulge in your vagina or that something is falling out from your vagina?

☐ Yes continue ☐ No go to question # 16

a. How much are you bothered by this sensation or bulge?
(Please place an "I" on the line.)

Not at all ———— Greatly

16. Do you wear anything in your vagina such as a pessary or tampon to prevent a sensation of bulge or pressure from happening?

☐ Yes ☐ No

If you answered yes to EITHER of the pelvic prolapse questions above (question 15 or 16), please continue. If you answered no to BOTH of these questions, please go to question #18.

17. Have you ever asked a doctor, nurse, or other healthcare professional for help with pelvic prolapse?

☐ Yes ☐ No

18. Have you had any surgery to correct pelvic prolapse?

☐ Yes continue ☐ No go to question # 19

a. How many surgeries have you had to correct pelvic prolapse?

☐ # of surgeries

Remember: Answer these questions based on your CURRENT SYMPTOMS.

Pelvic Floor Health Questionnaire

Some women will experience problems with their bowels including difficulty passing stools, or involuntary loss of solid stool, liquid stool, or gas from the rectum. Please answer each of the following questions about these problems to the best of your ability.

19. Do you ever have difficulty having a bowel movement?

☐ Yes continue ☐ No go to question # 20

a. How often do you have difficulty having a bowel movement?

☐ Less than once per year

☐ More than once per year, but less than once per month

☐ More than once per month, but less than once per week

☐ At least once per week, but not every day

☐ Every day

b. How much are you bothered by difficulty having a bowel movement?
(Please place an "I" on the line.)

Not at all ———— Greatly

c. For how long has this difficulty having a bowel movement been a problem?

☐ Less than a year ☐ Six to ten years

☐ One to five years ☐ More than ten years

Remember: Answer these questions based on your CURRENT SYMPTOMS.

Pelvic Floor Health Questionnaire

Participant ID ☐☐☐☐

20. Do you ever have to push on your vagina or around your rectum to have a complete bowel movement?

☐ Yes continue ☐ No go to question # 21

GETTING CLOSER

a. How often does this occur?

- ☐ Less than once per year
- ☐ More than once per year, but less than once per month
- ☐ More than once per month, but less than once per week
- ☐ At least once per week, but not every day
- ☐ Every day

b. How much are you bothered by pushing on your vagina or around your rectum?
(Please place an "I" on the line.)

Not at all ———————————————— Greatly

21. How often do you use laxatives or stool softeners (not including high fiber supplements like Metamucil)?

☐ Never ☐ Rarely ☐ Monthly ☐ Weekly ☐ Daily

22. Do you lose gas from your rectum that is beyond your control?

☐ Yes continue ☐ No go to question # 23

Remember: Answer these questions based on your CURRENT SYMPTOMS.

Pelvic Floor Health Questionnaire

a. How often do you lose gas from your rectum beyond your control?

- ☐ Less than once per year
- ☐ More than once per year, but less than once per month
- ☐ More than once per month, but less than once per week
- ☐ At least once per week, but not every day
- ☐ Every day

b. How much are you bothered by losing gas from your rectum?
(Please place an "I" on the line.)

Not at all ———————————————— Greatly

23. Do you lose stool beyond your control if your stool is loose or liquid?

☐ Yes continue ☐ No go to question # 24

a. How often do you lose loose or liquid stool?

- ☐ Less than once per year
- ☐ More than once per year, but less than once per month
- ☐ More than once per month, but less than once per week
- ☐ At least once per week, but not every day
- ☐ Every day

b. How much are you bothered by losing loose or liquid stool?
(Please place an "I" on the line.)

Not at all ———————————————— Greatly

Remember: Answer these questions based on your CURRENT SYMPTOMS.

Pelvic Floor Health Questionnaire

Participant ID ☐☐☐☐

24. Do you lose well-formed stool beyond your control?

☐ Yes continue ☐ No go to question # 25

a. How often do you lose well-formed stool?

- ☐ Less than once per year
- ☐ More than once per year, but less than once per month
- ☐ More than once per month, but less than once per week
- ☐ At least once per week, but not every day
- ☐ Every day

A LITTLE FURTHER

b. How much are you bothered by loss of well-formed stool?
(Please place an "I" on the line.)

Not at all ———————————————— Greatly

25. Do you wear liners, pads, diapers, or toilet paper, or do you change your undergarments to protect your clothes from loss of stool?

☐ Yes ☐ No

If you answered "yes" to ANY of the questions about stool or gas (questions 22–25), please continue. If you answered "no" to ALL of these questions, please go to question 27.

26. Have you ever asked a doctor, nurse, or other healthcare professional for help with the loss of stool or gas?

☐ Yes ☐ No

Remember: Answer these questions based on your CURRENT SYMPTOMS.

Pelvic Floor Health Questionnaire

27. Have you had any surgery to correct the loss of stool or gas?

☐ Yes ☐ No

a. If yes, how many surgeries have you had to correct this problem?

☐☐ # of surgeries

We realize that this is a long survey and greatly appreciate your valuable time. The results that we obtain from this study are very important and will help physicians and other health care professionals better care for all women in the future.

FINISHED!

Thank you for completing this survey!

Remember: Answer these questions based on your CURRENT SYMPTOMS.

APPENDIX D

BONE LOADING HISTORY QUESTIONNAIRE

Physical Activity History Questionnaire

BLHQ-1

Instructions:

1. Please list activities you **most often** participated in during each of the five reference periods on the pages that follow.
   a. please refer to the list of activities provided below to assist you with recall. You are not limited to this list.
2. For each activity you list:
   a. please check the **seasons** that you participated
   b. please indicate the **number of years** you participated
   c. please check the **frequency** you participated
3. The activity headings are to assist you with recall. If you run out of space, use a row under a different heading.
4. Please circle the type of environment you lived in during each reference period.

This is a sample response for elementary school.

Activities	Season				# years (max 6)	1 - 3 times a month	1- 2 times a week	3 - 5 times a week	> 5 times a week
	Summer	Fall	Winter	Spring					
During School									
Jump rope		x		x	5			x	
Kickball		x		x	2		x		
Leisure Time (after school, weekends)									
Bike riding	x				6				x
Ice skating			x		1	x			
Organized Sports									
Swimming	x	x	x	x	3			x	

How would you characterize the environment you lived in during this time period?

a. big city (urban) b. moderate/small town (suburban) c. country/farm (rural)

How would you characterize your level of competition during this period?

a. Recreational
b. High School
Junior Varsity or Varsity
c. Collegiate
d. Semi Professional
e. Professional

Physical Activities List (you are not limited to this list!)

aerobics/step	dodgeball	hopscotch	skiing/alpine/water	tennis
ballet/jazz/tap	football/flag	horseback riding	skiing/cross-country	tetherball
basketball	four-square	jump rope	snowboarding	track (throwing)
biking/mountain	gardening	kickball	soccer	track (jumping/sprinting)
biking/road	golf	racquetball/handball	softball/baseball	volleyball
cheerleading	gymnastics	running/jogging	swimming	walking
dancing	hiking	skating/roller/ice	tag/chase	weight lifting (machines)
				weight lifting (free weights)

BLHQ-2

Reference Period: Elementary School (grade k - 5)

Activities	Season				# years (max 6)	1 - 3 times a month	1 - 2 times a week	3 - 5 times a week	> 5 times a week
	Summer	Fall	Winter	Spring					
During School									
Leisure Time (after school, weekends)									
Organized Sports									

How would you characterize the environment you lived in during this time period?	How would you characterize your level of competition during this period?
a. big city (urban)	a. Recreational; c. Collegiate
b. moderate/small town (suburban)	b. High School Junior Varsity or Varsity; d. Semi Professional
c. country/farm (rural)	e. Professional

Physical Activities List (you are not limited to this list!)

aerobics/step
ballet/jazz/tap
basketball
biking/mountain
biking/road
cheerleading
dancing
dodgeball
football/flag
four-square
gardening
golf
gymnastics
hiking
hopscotch
horseback riding
jump rope
kickball
racquetball/handball
running/jogging
skating/roller/ice
skiing/alpine/water
skiing/cross-country
snowboarding
soccer
softball/baseball
swimming
tag/chase
tennis
tetherball
track (throwing event)
track (jumping/sprinting event)
volleyball
walking
weight lifting (machines)
weight lifting (free weights)

Reference Period: Junior High School (grade 6 - 8)

BLHQ-3

Activities	Season: Summer	Fall	Winter	Spring	# years (max 3)	1 - 3 times a month	1 - 2 times a week	3 - 5 times a week	> 5 times a week
During School									
Leisure Time (after school, weekends)									
Organized Sports									

How would you characterize the environment you lived in during this time period?
a. big city (urban)
b. moderate/small town (suburban)
c. country/farm (rural)

How would you characterize your level of competition during this period?
a. Recreational
b. High School
Junior Varsity or Varsity
c. Collegiate
d. Semi Professional
e. Professional

Physical Activities List (you are not limited to this list!)

aerobics/step	dodgeball	hopscotch	skiing/alpine/water	tennis
ballet/jazz/tap	football/flag	horseback riding	skiing/cross-country	tetherball
basketball	four-square	jump rope	snowboarding	track (throwing event)
biking/mountain	gardening	kickball	soccer	track (jumping/sprinting event)
biking/road	golf	racquetball/handball	softball/baseball	volleyball
cheerleading	gymnastics	running/jogging	swimming	walking
dancing	hiking	skating/roller/ice	tag/chase	weight lifting (machines)
				weight lifting (free weights)

Reference Period: Young Adult (age 18 - 29)

BLHQ-5

Activities	Season: Summer	Fall	Winter	Spring	# years (max 12)	1 - 3 times a month	1 - 2 times a week	3 - 5 times a week	> 5 times a week
Leisure Time									
Organized Sports									

How would you characterize the environment you lived in during this time period?	How would you characterize your level of competition during this period?	
a. big city (urban)	a. Recreational	c. Collegiate
b. moderate/small town (suburban)	b. High School	d. Semi Professional
c. country/farm (rural)	Junior Varsity or Varsity	e. Professional

Physical Activities List (you are not limited to this list!)

aerobics/step	dodgeball	hopscotch	skiing/alpine/water	tennis
ballet/jazz/tap	football/flag	horseback riding	skiing/cross-country	tetherball
basketball	four-square	jump rope	snowboarding	track (throwing events)
biking/mountain	gardening	kickball	soccer	track (jumping/sprinting events)
biking/road	golf	racquetball/handball	softball/baseball	volleyball
cheerleading	gymnastics	running/jogging	swimming	walking
dancing	hiking	skating/roller/ice	tag/chase	weight lifting (machines)
				weight lifting (free weights)

Reference Period: Adult (age 30 - 35)

BLHQ-6

Activities	Season				# years (max 5)	1 - 3 times a month	1 - 2 times a week	3 - 5 times a week	> 5 times a week
	Summer	Fall	Winter	Spring					
Leisure Time									
Organized Sports									

How would you characterize the environment you lived in during this period?	How would you characterize your level of competition during this period?	
a. big city (urban)	a. Recreational	c. Collegiate
b. moderate/small town (suburban)	b. High School	d. Semi Professional
c. country/farm (rural)	Junior Varsity or Varsity	e. Professional

Physical Activities List (you are not limited to this list!)

aerobics/step	dodgeball	hopscotch	skiing/alpine/water	tennis
ballet/jazz/tap	football/flag	horseback riding	skiing/cross-country	tetherball
basketball	four-square	jump rope	snowboarding	track (throwing events)
biking/mountain	gardening	kickball	soccer	track (jumping/sprinting events)
biking/road	golf	racquetball/handball	softball/baseball	volleyball
cheerleading	gymnastics	running/jogging	swimming	walking
dancing	hiking	skating/roller/ice	tag/chase	weight lifting (machines)
				weight lifting (free weights)

Reference Period: Past Year

BLHQ-7

Activities	Season				1 - 3 times a month	1 - 2 times a week	3 - 5 times a week	> 5 times a week
	Summer	Fall	Winter	Spring				
Leisure Time								
Organized Sports								

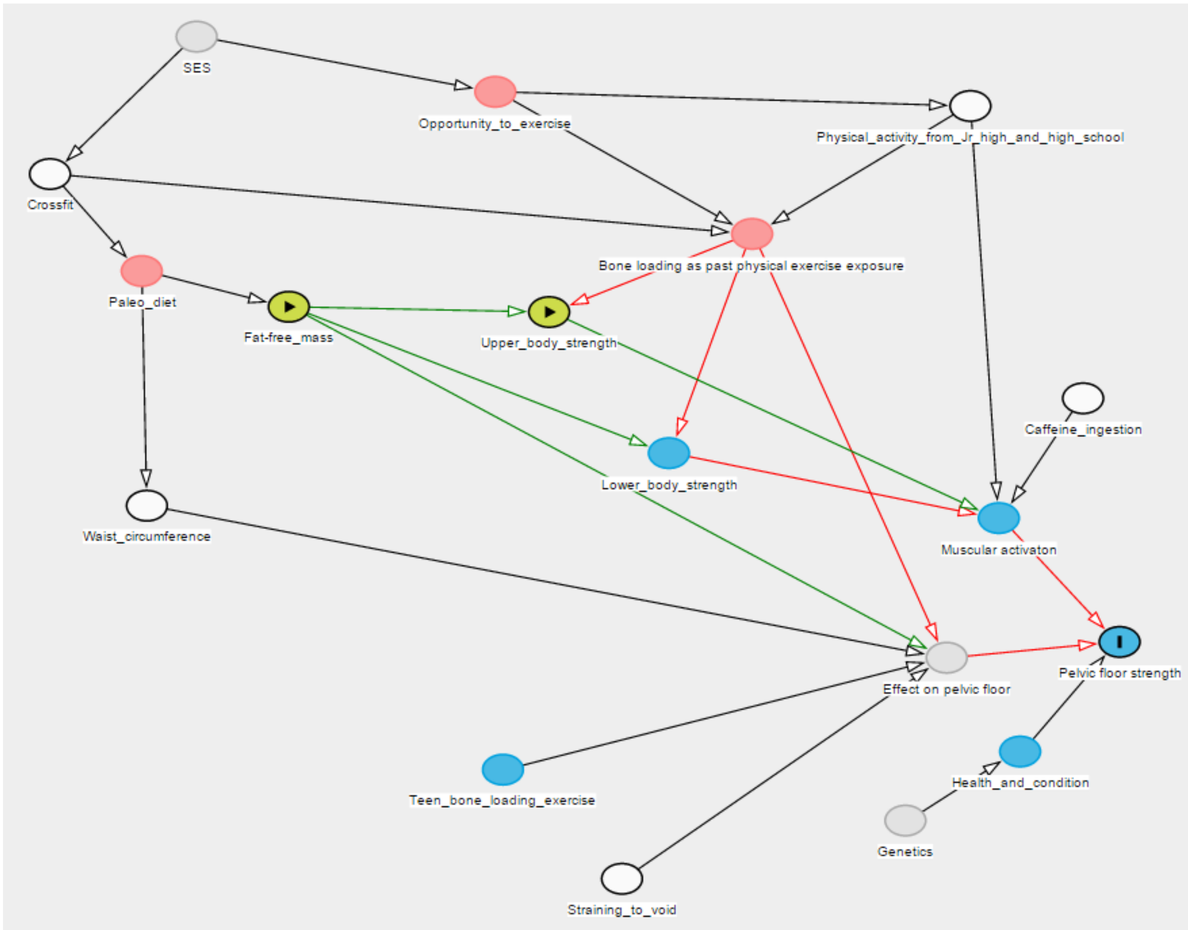
How would you characterize the environment you lived in during this period?	How would you characterize your level of competition during this period?	
a. big city (urban)	a. Recreational	c. Collegiate
b. moderate/small town (suburban)	b. High School	d. Semi Professional
c. country/farm (rural)	Junior Varsity or Varsity	e. Professional

Physical Activities List (you are not limited to this list!)

aerobics/step	dodgeball	hopscotch	tennis
ballet/jazz/tap	football/flag	horseback riding	tetherball
basketball	four-square	jump rope	track (throwing events)
biking/mountain	gardening	kickball	track (jumping/sprinting events)
biking/road	golf	racquetball/handball	volleyball
cheerleading	gymnastics	running/jogging	walking
dancing	hiking	skating/roller/ice	weight lifting (machines)
			weight lifting (free weights)

APPENDIX E

DIRECTED ACYCLIC GRAPH


SES
Opportunity_to_exercise
Physical_activity_from_Jr_high_and_high_school
Crossfit
Bone loading as past physical exercise exposure
Paleo_diet
Fat-free_mass
Upper_body_strength
Caffeine_ingestion
Lower_body_strength
Waist_circumference
Muscular activaton
Pelvic floor strength
Effect on pelvic floor
Teen_bone_loading_exercise
Health_and_condition
Genetics
Straining_to_void

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